
EURAMET.M.FF-S16

Calibration of piston operated volumetric instruments

SUPPLEMENTARY COMPARISON

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EURAMET.M.FF-S16
Comparison of piston-operated volumetric instruments
(EURAMET project 1533)

Supplementary comparison

Final Report

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Support

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1 Document control

Version Draft A.1	Issued on 18 April 2024
Version B	Issued on 20 September 2024
Version B.1	Issued on 13 November 2024
Final Report	Issued on 30 March 2026

2 Introduction

The objective of this comparison is to compare the calibration results of piston – operated volumetric instruments: (0,2 – 10) μL micropipette, 50 mL piston burette and 1 mL glass syringe. Furthermore, this comparison is intended to be used to support the calibration and measurement capabilities (CMCs) of the participants in the calibration of piston – operated volumetric instruments.

This comparison has been organized within EURAMET with project number 1533 and has been also registered in the BIPM KCDB as EURAMET.M.FF-S16. The comparison was approved during the online EURAMET TCF volume subgroup meeting 2021 and officially started in January 2022, the final measurements were performed in November 2023 and the last participant's reports received in April 2024.

This comparison was organized and carried out according to the MRA rules [1].

3 Participants and organisation of the comparison

3.1 Coordinator and member of the support

The pilot laboratory for the comparison is DMDM (Republic of Serbia).

The co-pilot for the comparison is IPQ (Portugal).

Coordinator:

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Support:

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3.2 List of participants

In May 2022, INM-RO, Romania joined the comparison after it started.

Table 1: Participants

Participant	Contact person	e-mail	Address
DMDM	Ljiljana Mičić	ljmicic@dmdm.rs	Directorate of Measures and Precious metals, Mike Alasa 14, 11000 Belgrade, REPUBLIC OF SERBIA
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MIRS	Urška Turnšek	Urska.Turnsek@gov.si	Metrology Institute of the Republic of Slovenia, Tkalska ulica 15, SI-3000 Celje, SLOVENIA
BFKH	Csilla Vámosy	vamosy.csilla@bfkh.gov.hu	Budapest Főváros Kormányhivatala 1124 Budapest, Németvölgyi út 37-39. HUNGARY
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RISE	Per Wennergren	per.wennergren@ri.se	Research Institutes of Sweden, Brinellgatan 4, SE-50462 Borås, SWEDEN
VSL	Erik Smits	fsmits@vsl.nl	VSL B.V. Hugo de Grootplein 1, 3314 EG Dordrecht, NETHERLANDS
SASO - NMCC	Abdulkarim A. Al-shahrani	a.shahrany@saso.gov.sa	SASO, Riyadh - Imam Saud bin Abdulaziz bin Mohammed Road, the intersection of Prince Turki bin Abdulaziz I Road BOX 3437 Riyadh 11471, Kingdom of Saudi Arabia
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INM	Istrate Florin	florin.istrate@inm.ro	National Institute of Metrology (INM) code zip 042 122, Bucuresti Sos. Vitan-Bărzesti, nr. 11 Sector 4
IPQ	Elsa Batista	ebatista@ipq.pt	Portuguese Institute for Quality Rua António Gião, 2 2829-513 Caparica, PORTUGAL

3.3 Organisation and comparison schedule

The circulation of the transfer standards started in January 2022 and was completed in November 2023. The detailed time schedule for the comparison is given in Tables 2 and 3.

A period of one month was originally allowed for the measurements in each laboratory, including the time necessary for transportation.

For the transport, the transfer standards were packed in two transportation boxes, the micropipette was in one and the syringe with piston burette was in another transportation box because of different owners and different documentation for import / export. This lead to different calibration period of the transfer standards.

Table 2. Period of realisation of comparison for micropipette

NMI	Country	Mean date of measurements	Period for measurements and transport
DMDM	Republic of Serbia	September 2021	1.9.2021. – 4.3.2022. ¹
IMBIH	Bosnia and Herzegovina	March 2022	4.3. – 23.3.2022.
UME	Turkey	March 2022	24.3. – 4.4.2022.
MIRS	Republic of Slovenia	April 2022	14.4. – 16.5.2022
BFKH	Hungary	not measured	17.5. – 30.5.2022.
ČMI	Czech Republic	June 2022	2. – 28.6.2022.
GUM	Poland	July 2022	30.6 – 29.7.2022.
FORCE	Denmark	August 2022	15.8. – 22.8.2022.
RISE	Sweden	September 2022	24.8. – 30.9.2022. ²
BMM	Montenegro	December 2022	15.11. – 21.12.2022.
INM	Romania	January 2023	4.1. – 19.1.2023.
DMDM	Republic of Serbia	not measured	6.2. – 8.2.2023. ³
SASO -NMCC	Saudi Arabia	March 2023	26.2. – 28.3.2023.
DMDM	Republic of Serbia	not measured	5.4. – 6.4.2023. ⁴
IPQ	Portugal	May 2023	6.4. – 25.5.2023.

Table 3. Period of realisation of comparison for syringe and piston burette

NMI	Country	Mean date of measurements	Period for measurements and transport
DMDM	Republic of Serbia	October 2021	1.10.2021. - 31.1.2022.
UME	Turkey	February 2022	16.2. – 7.3.2022.
IMBIH	Bosnia and Herzegovina	March 2022	11.3. – 12.4.2022.
MIRS	Republic of Slovenia	May 2022	19.5. – 10.6.2022. ⁵
BFKH	Hungary	June 2022	19.6. – 6.7.2022.
ČMI	Czech Republic	July 2022	8.7. – 26.7.2022.
GUM	Poland	August 2022	28.7. – 14.9.2022.
FORCE	Denmark	September 2022	16.9. – 30.9.2022.
RISE	Sweden	October 2022	4.10. – 2.11.2022.
VSL	Netherlands	December 2022	3.11. – 29.12.2022.
SASO - NMCC	Saudi Arabia	January	29.12. – 22.1.2023.
BMM	Montenegro	August 2023	13.2. – 7.8.2023. ⁶
INM	Romania	October 2023	3.10. – 8.11.2023. ⁷
IPQ	Portugal	November 2023	10.11. – 30.11.2023.

There were some delays in the planned circulation scheme that are signed in the table and this was mainly due to customs issues.

4 Transfer standards

Three different transfer standards were circulated in this comparison:

¹ Delay (custom issues)

² Delay (custom issues)

³ Returned to the pilot due to custom issues

⁴ Returned to the pilot due to custom issues

⁵ Delay (custom issues)

⁶ Delay (purchasing of recirculation tube for piston burette takes 5 months)

⁷ Delay (custom issues)

- 1) a variable 1-channel electronic micropipette, measuring range (0,2 – 10) μL , manufacturer Biohit (Sartorius), type Picus, ser. number 13008918 (see figure 1),
- 2) a glass syringe, measuring range (0 – 1) mL, manufacturer ILS, ser. number S1, inner diameter is 4,607 mm, (see figure 2),
- 3) a piston burette, measuring range (0 – 50) mL, manufacturer Brand, type Titrette, ser. number, 21F89857 (see figure 3).

The owner of the micropipette is DMDM, Serbia. The owner of the glass syringe and piston burette is IPQ, Portugal.

BIOHIT Picus electronic pipette User Manual was available on website <https://solutions.pipette.com/wp-content/uploads/Biohit-Picus-User-Manual.pdf>.

The micropipette needs to have attached a removable plastic tip in order to aspirate the liquid. DMDM supplied these tips that were provided from the manufacturer.

The piston burette was supplied with suitable adapters for any liquid container.

The micropipette and piston burette used for this comparison are essentially of plastic material with a cubic coefficient of thermal expansion of $2,4 \times 10^{-4} / ^\circ\text{C}$ [4]. This coefficient is linked to the material and is equal for every participant.

The glass syringe has a cubic coefficient of thermal expansion of $9,9 \times 10^{-6} / ^\circ\text{C}$ [3] and a removable tip is connected to the syringe in order to improve the delivery of liquid, it should not be removed.



Figure 1 - Micropipette



Figure 2 - Glass syringe



Figure 3 - Piston burette

4.1 Stability of the transfer standards

Two different measurements of micropipette were performed by the pilot laboratory and two different measurements of piston burette and syringe were performed by the co-pilot laboratory during the comparison in order to verify the stability of the standards.

Table 4. Stability of the transfer standards

	Measurement	Date	Volume	Uncertainty	ΔV
Micropipette	1	September 2021.	10,027 μL	0,025 μL	0,016 μL
	2	June 2023.	10,041 μL	0,023 μL	
Piston burette	1	August 2021.	50,0090 mL	0,0092 mL	0,0011 mL
	2	November 2023.	50,0101 mL	0,0071 mL	
Syringe	1	August 2021.	1,00308 mL	0,002 mL	0,00017 mL
	2	November 2023.	1,00325 mL	0,002 mL	

The variation found in all instruments is smaller than the claimed uncertainty and therefore it is verified that the instruments are stable for the entire comparison.

5 The measurement procedure

All the participating NMIs used the gravimetric method, to determine the amount of water that the instruments deliver at reference temperature of 20 °C, based on ISO standard 4787 [3] and ISO 8655 [2], with equation (1):

$$V_{20} = (I_I - I_E) \times \frac{1}{\rho_W - \rho_A} \times \left(1 - \frac{\rho_A}{\rho_B}\right) \times [1 - \gamma(t - 20)] \quad (1)$$

Where:

V_{20} volume, at the 20 °C , in μL

I_I weighing result of the recipient full of liquid, in mg

I_E weighing result of the empty recipient, in mg

ρ_W water density, in mg/ μL , at the calibration temperature t , in °C, is advisable to use the Tanaka density formula [7]

ρ_A air density, in mg/ μL

ρ_B density of masses used during measurement (substitution) or during calibration of the balance, in mg/ μL

γ cubic thermal expansion coefficient of the material of the instruments, in °C⁻¹

t water temperature used in the calibration, in °C

6 Equipment, calibration liquid characteristics and ambient conditions of the participants

All instruments and ambient conditions used by the NMIs are described in Annex 1. In general, all participants used the equipment and ambient temperature recommended by the relevant standards.

7 Measurement results

The results for all three transfer standards reported by the participating laboratories are included in table 5.

Table 5. Laboratory results

Code	Micropipette		Piston burette		Syringe	
	$V/\mu\text{L}$	$U/\mu\text{L}$	V/mL	U/mL	V/mL	U/mL
GUM	10,018	0,025	50,006	0,007	1,0017	0,003
	4,988	0,025	25,0019	0,0062		
	0,997	0,025	5,0008	0,0058		
	0,213	0,025				

MBM	10,046 5,002 1,009 0,227	0,04 0,04 0,034 0,02	49,9999 25,002 4,9997	0,007 0,007 0,007	1,003031	0,003
IPQ	10,041 4,996 1,001 0,227	0,023 0,013 0,011 0,011	50,0101 25,008 5,0028	0,0071 0,0073 0,0062	1,00325	0,002
BFKH	_8		49,987 24,990 4,998	0,008 0,007 0,006	1,0013	0,006
MIRS	10,024 4,990 1,029 0,226	0,02 0,018 0,025 0,013	50,0156 25,0042 5,0033	0,009 0,008 0,0028	1,004	0,004
ČMI	9,998 4,995 1,005 _9	0,028 0,019 0,012 _10	50,010 25,006 5,0037	0,021 0,012 0,0066	_11	
DMDM	10,027 4,999 1,005 0,21	0,06 0,059 0,058 0,041	50,008 25,003 5,002	0,008 0,009 0,005	1,001	0,002
SASO	10,088 5,031 1,03874 0,238774	0,049828 0,029223 0,016278 0,01642	50,0018982 25,0033793 5,002559	0,0111597 0,007636 0,005909	1,0023983	0,003114
RISE	10,027 5,027 1,043 0,253	0,046 0,028 0,019 0,009	49,9883 24,9899 4,9992	0,0096 0,0086 0,0082	1,00072	0,0058
VSL	_12		50,0153 25,0115 5,0031	0,0094 0,0086 0,0084	_13	
FORCE	10,06 5,025 1,054 _14	0,086 0,084 0,073 _15	50,007 25,001 5,003	0,016 0,015 0,012	1,0006	0,0047
UME	10,052 5,023 1,032 _16	0,043 0,042 0,041 _17	49,99775 24,99821 4,99961	0,00927 0,00687 0,00593	1,00142	0,002206

⁸ Not measured

⁹ Not measured

¹⁰ Not measured

¹¹ Not measured

¹² Not measured

¹³ Not measured

¹⁴ Not measured

¹⁵ Not measured

¹⁶ Not measured

¹⁷ Not measured

INM	10,0230 4,979 0,9955 _18	0,0183645 0,0162868 0,0146815 _19	50,00581 25,001965 5,000649	0,005916754 0,008124627 0,005977712	0,999453	0,0018857
IMBIH	10,001 4,982 0,998 _20	0,074 0,073 0,072 _21	50,007 25,004 5,001	0,013 0,008 0,006	1,000138	0,002008

8 Determination of the reference value

To determine the reference value of this comparison (KCRV) the weighted mean (3) was selected, using the inverses of the squares of the associated standard uncertainties as the weights [7], according to the instructions given by the BIPM:

$$y = \frac{x_1/u^2(x_1) + \dots + x_n/u^2(x_n)}{1/u^2(x_1) + \dots + 1/u^2(x_n)} \quad (3)$$

To calculate the standard deviation $u(y)$ associated with the volume y [7] equation (4) was used:

$$u(y) = \sqrt{\frac{1}{1/u^2(x_1) + \dots + 1/u^2(x_n)}} \quad (4)$$

The expanded uncertainty of the reference value is $U(y) = 2 \times u(y)$.

To identify an overall consistency of the results a chi-square test can be applied to all n calibration results [7].

$$\chi_{obs}^2 = \frac{(x_1 - y)^2}{u^2(x_1)} + \dots + \frac{(x_n - y)^2}{u^2(x_n)} \quad (5)$$

where the degrees of freedom are: $\nu = n - 1$

The consistency check is regarded as failed if: $\Pr\{\chi^2(\nu) > \chi_{obs}^2\} < 0,05$. The function CHIINV(0,05; n-1) in MS Excel was used. The consistency check was failing if $\text{CHIINV}(0,05; n-1) < \chi_{obs}^2$.

If the consistency check did not fail then y was accepted as the KCRV x_{ref} and $U(x_{ref})$ was accepted as the expanded uncertainty of the KCRV.

If the consistency check failed then the laboratory with the highest value of $\frac{(x_i - y)^2}{u^2(x_i)}$ is excluded from the next round of evaluation and the new reference value, reference standard uncertainty and chi-squared value is calculated again without the excluded laboratory. When the consistency check passes, for each laboratory results, x_i the degree of equivalence d_i between each laboratory and the KCRV (x_{ref}) is calculated using the following formulas [7]:

$$d_i = x_i - x_{ref} \quad (6)$$

$$U(d_i) = 2 \times u(d_i) \quad (7)$$

where $u(d_i)$ is calculated from

¹⁸ Not measured

¹⁹ Not measured

²⁰ Not measured

²¹ Not measured

$$u^2(d_i) = u^2(x_i) - u^2(x_{ref}) \quad (8)$$

Discrepancy values can be identify if $|d_i| > 2u(d_i)$.

To calculate the degrees of equivalence d_{ij} between the laboratories the following formulas are used [7]:

$$d_{i,j} = x_i - x_j \quad (9)$$

$$U(d_{i,j}) = 2 \times u(d_{i,j}) \quad (10)$$

Where $u(d_{i,j})$ is calculated from

$$u^2(d_{i,j}) = u^2(x_i) + u^2(x_j) \quad (11)$$

The factor 2 in equation (7 and 10) corresponds to 95 % coverage under the assumption of normality.

9 Results with reference value and RV uncertainty

9.1 Results with reference value and RV uncertainty for syringe

The obtained reference value is 1,002 mL. The expanded uncertainty $U = 2 \times u(y)$ of the reference value is: 0,001 mL.

The calculated value $\chi^2(v) = 19,68$ is larger than the observed value $\chi^2_{obs} = 10,44$, therefore the set of results are consistent from a statistical point of view and the reference value is accepted.

All the measurement results, the reference value and its uncertainty are presented in the following figure 4:

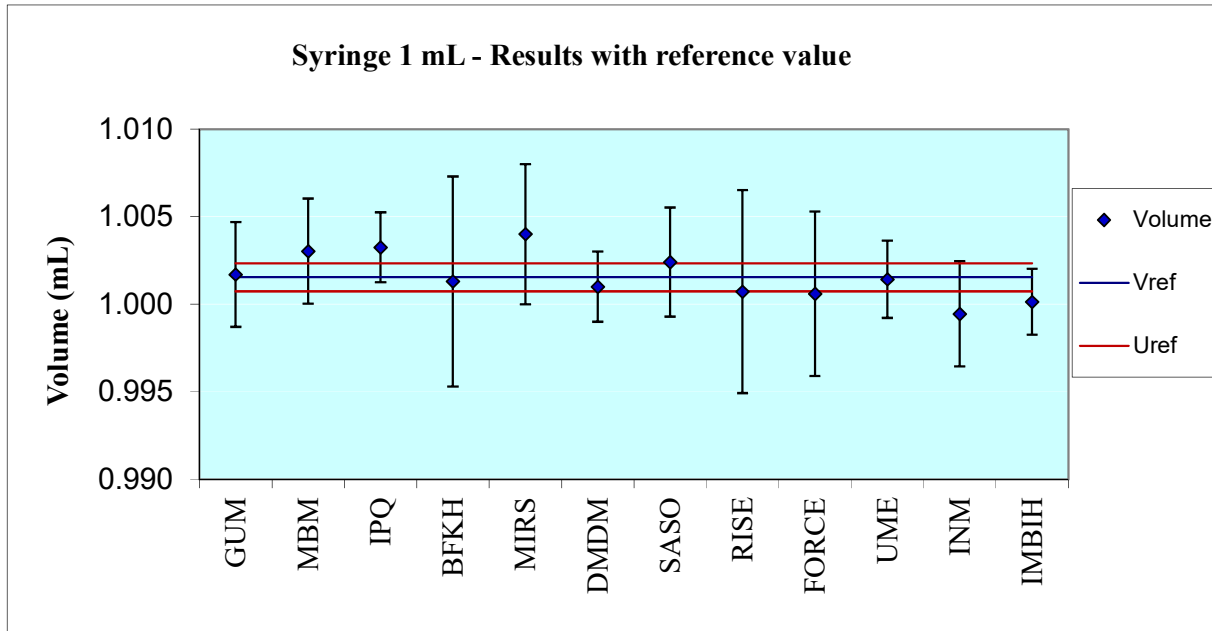


Figure 4 – Syringe results with reference value

The degree of equivalence with the RV is presented in figure 5:

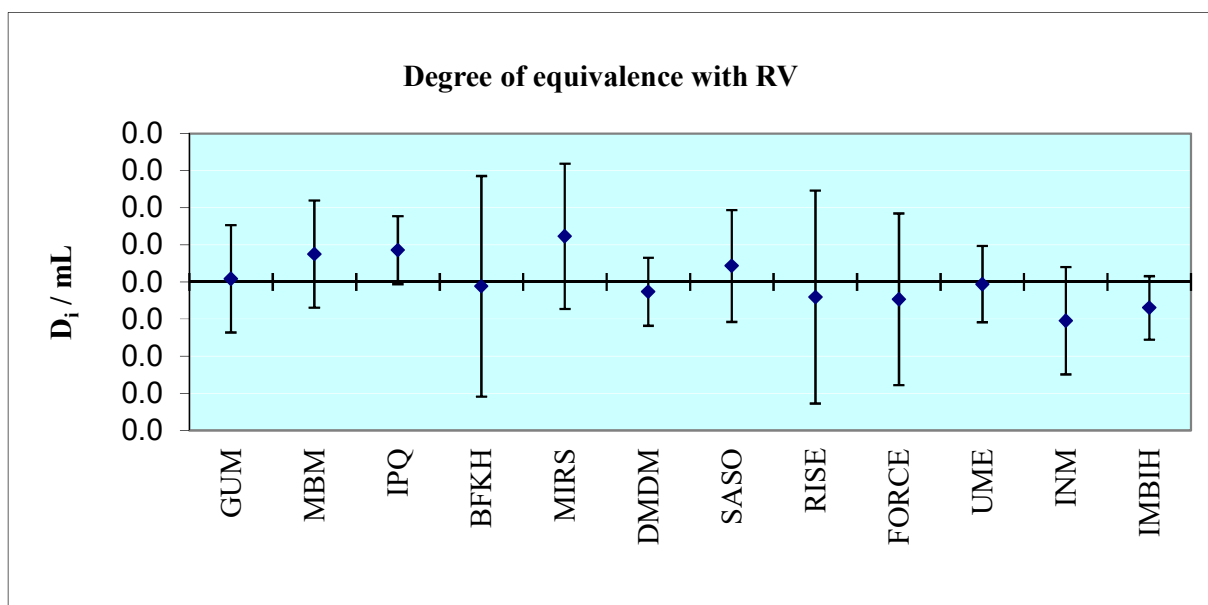


Figure 5 – Degree of equivalence syringe

Table 6. Degree of equivalence with RV

Laboratory	d_i (mL)	Ud_i (mL)	E_i
GUM	0,000	0,003	0,06
MBM	0,001	0,003	0,52
IPQ	0,002	0,002	0,93
BFKH	0,000	0,006	-0,04
MIRS	0,002	0,004	0,63
DMDM	-0,001	0,002	-0,29
SASO	0,001	0,003	0,29
RISE	-0,001	0,006	-0,14
FORCE	-0,001	0,005	-0,20
UME	0,000	0,002	-0,06
INM	-0,002	0,003	-0,72
IMBIH	-0,001	0,002	-0,82

9.2 Results with reference value and RV uncertainty for piston burette

For the burette it was decided to consider only the 50 mL has official results. The value 5 mL and 25 mL results are in Annex 2 and will not serve for CMC validation since the uncertainty of the resolution of the device is more than 50 % of the total uncertainty.

9.2.1 50 mL

The obtained reference value is 50,004 mL. The expanded uncertainty $U = 2 \times u(y)$ of the reference value is: 0,002 mL.

The calculated value $\chi^2(\nu) = 22,36$ is smaller than observed value $\chi^2_{obs} = 49,84$, this means that the chi-square test failed and the results are not consistent.

After removal two outliers, the obtained reference value is 50,007 mL. The expanded uncertainty $U = 2 \times u(y)$ of the reference value is: 0,003 mL.

The calculated value $\chi^2(\nu) = 19,68$ is larger than observed value $\chi^2_{obs} = 16,70$, therefore the set of results are consistent from a statistical point of view and the reference value is accepted.

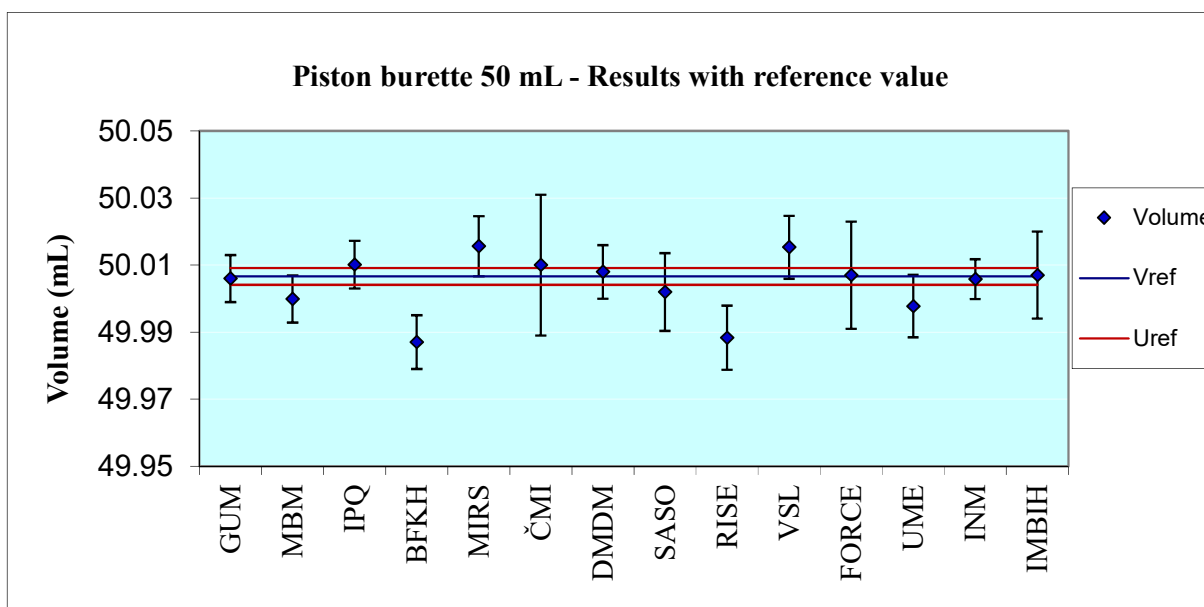


Figure 6 – Piston burette results at 50 mL with reference value

The degree of equivalence with the RV is presented in figure 7.

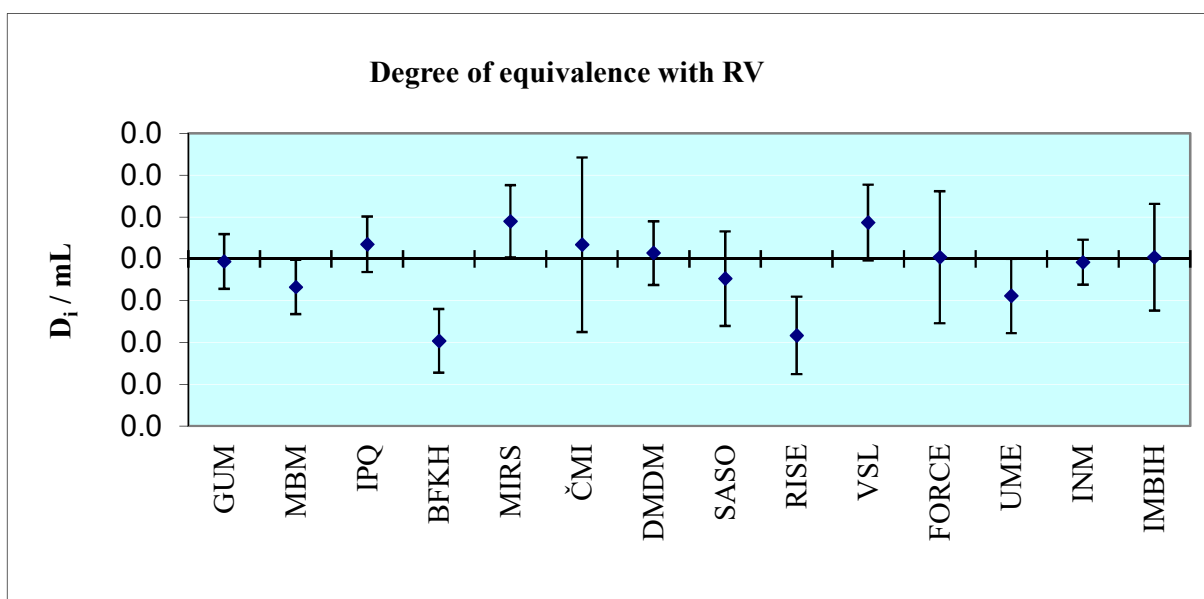


Figure 7 – Degree of equivalence burette 50 mL

Table 7. Degree of equivalence with RV

Laboratory	$D_i(\text{mL})$	$Ud_i(\text{mL})$	E_i	Info
GUM	-0,001	0,007	-0,09	
MBM	-0,007	0,007	-1,03	
IPQ	0,003	0,007	0,52	
BFKH	-0,020	0,008	-2,58	Excluded
MIRS	0,009	0,009	1,04	
ČMI	0,003	0,021	0,16	
DMDM	0,001	0,008	0,18	
SASO	-0,005	0,011	-0,42	

RISE	-0,018	0,009	-1,98	Excluded
VSL	0,009	0,009	0,96	
FORCE	0,000	0,016	0,02	
UME	-0,009	0,009	-0,99	
INM	-0,001	0,005	-0,15	
IMBIH	0,000	0,013	0,03	

9.3 Results with reference value and RV uncertainty for micropipette

9.3.1 10 μL

The obtained reference value is 10,027 μL . The expanded uncertainty $U = 2 \times u(y)$ of the reference value is: 0,009 μL .

The calculated value $\chi^2(\nu) = 19,68$ is larger than the observed value $\chi^2_{obs} = 15,89$, therefore the set of results are consistent from a statistical point of view and the reference value is accepted.

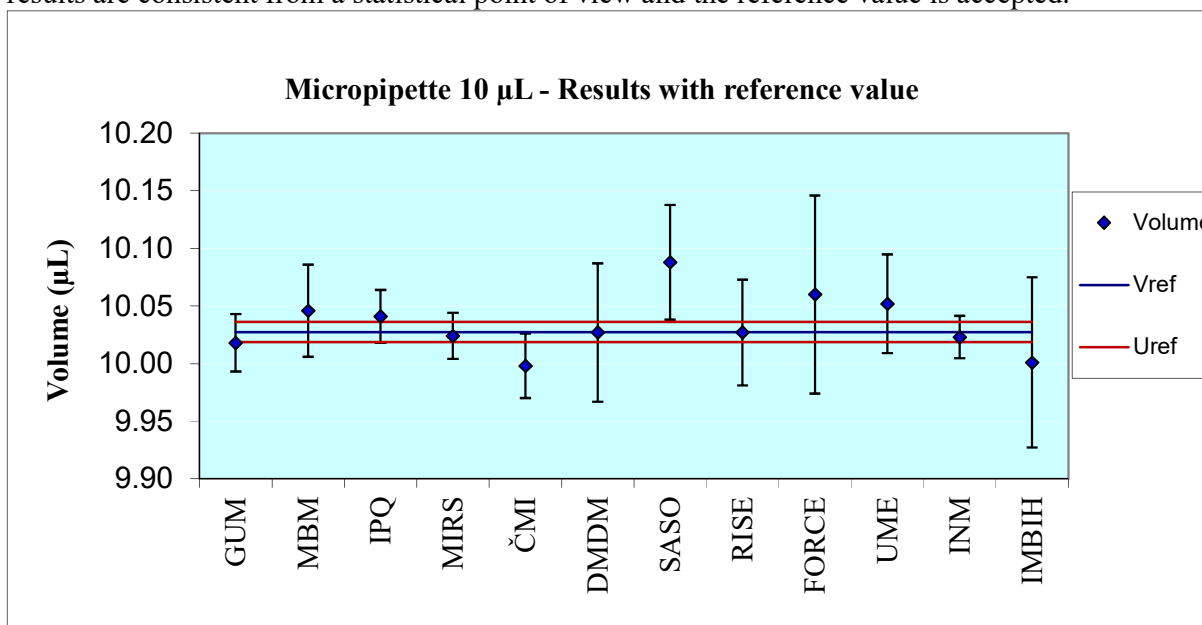


Figure 8 – Micropipette results at 10 μL with reference value

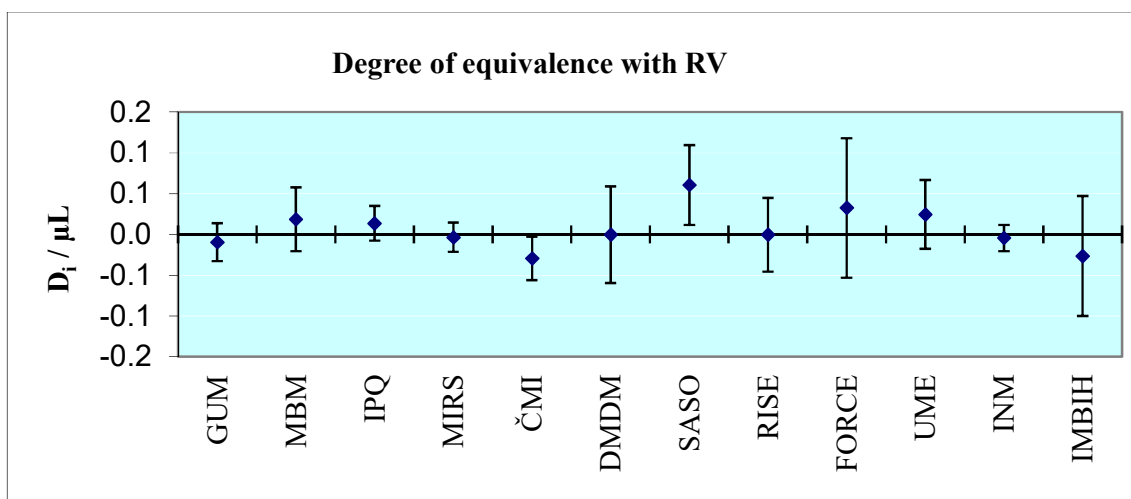


Figure 9 – Degree of equivalence, micropipette results at 10 μL

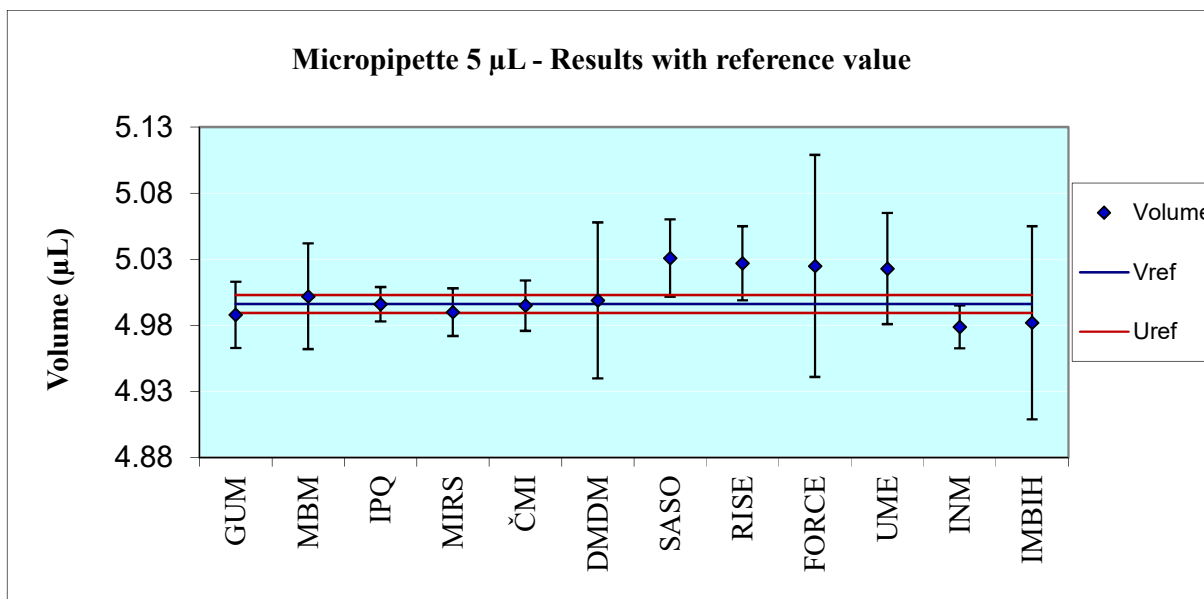
Table 8. Degree of equivalence with RV

Laboratory	$D_i(\mu\text{L})$	$Ud_i(\mu\text{L})$	E_i
GUM	-0,01	0,02	-0,40
MBM	0,02	0,04	0,48
IPQ	0,01	0,02	0,64
MIRS	0,00	0,02	-0,19
ČMI	-0,03	0,03	-1,11
DMDM	0,00	0,06	-0,01
SASO	0,06	0,05	1,24
RISE	0,00	0,05	-0,01
FORCE	0,03	0,09	0,38
UME	0,02	0,04	0,58
INM	0,00	0,02	-0,27
IMBIH	-0,03	0,07	-0,36

9.3.2 5 μL

The obtained reference value is 4,996 μL . The expanded uncertainty $U = 2 \times u(y)$ of the reference value is: 0,007 μL .

The calculated value $\chi^2(\nu) = 19,68$ is larger than the observed value $\chi^2_{obs} = 18,24$, therefore the set of results are consistent from a statistical point of view and the reference value is accepted.



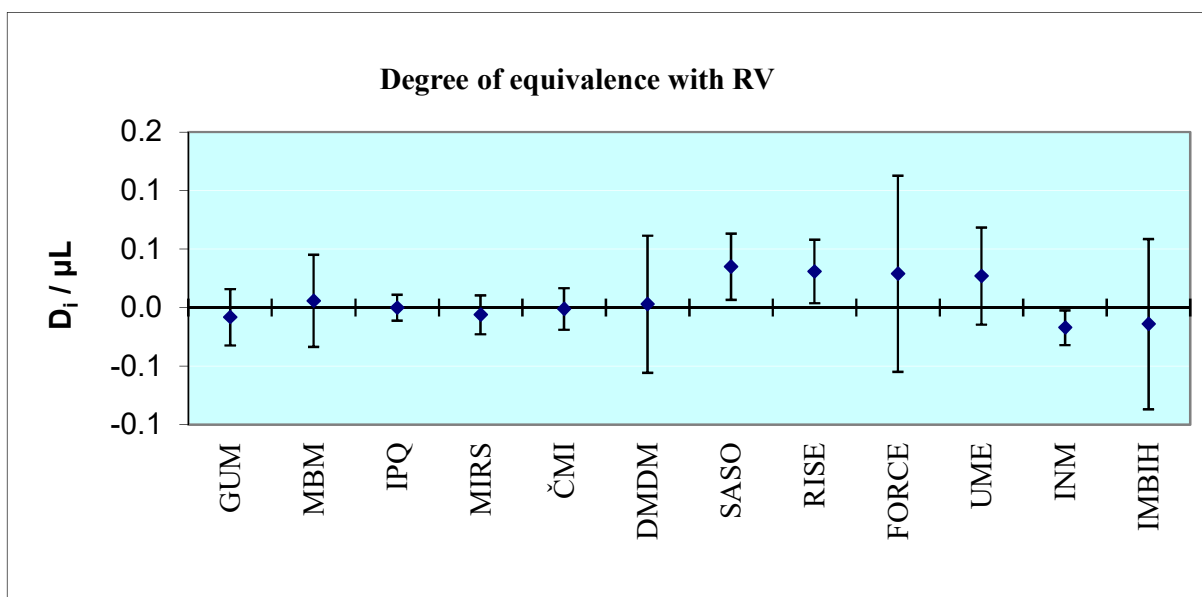


Figure 11 – Degree of equivalence micropipette results at 5 µL

Table 9. Degree of equivalence with RV

Laboratory	$D_i(\mu\text{L})$	$U_{D_i}(\mu\text{L})$	E_i
GUM	-0,01	0,02	-0,34
MBM	0,01	0,04	0,15
IPQ	0,00	0,01	-0,02
MIRS	-0,01	0,02	-0,37
ČMI	0,00	0,02	-0,07
DMDM	0,00	0,06	0,05
SASO	0,03	0,03	1,23
RISE	0,03	0,03	1,14
FORCE	0,03	0,08	0,34
UME	0,03	0,04	0,65
INM	-0,02	0,01	-1,16
IMBIH	-0,01	0,07	-0,20

9.3.3. 1 µL

The obtained reference value is 1,012 µL. The expanded uncertainty $U = 2 \times u(y)$ of the reference value is: 0,006 µL.

The calculated value $\chi^2(\nu) = 19,68$ is smaller than observed value $\chi^2_{obs} = 37,64$, this means that the chi-square test failed and the results are not consistent.

After removal two outliers, the obtained reference value is 1,004 µL. The expanded uncertainty $U = 2 \times u(y)$ of the reference value is: 0,006 µL.

The calculated value $\chi^2(\nu) = 16,92$ is larger than observed value $\chi^2_{obs} = 9,84$, therefore the set of results are consistent from a statistical point of view and the reference value is accepted.

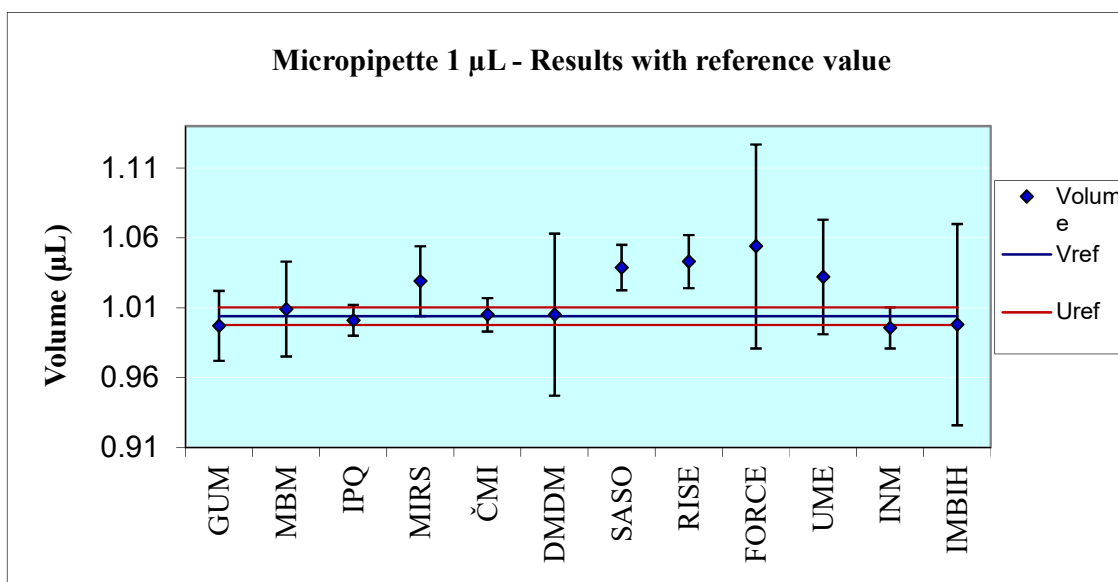


Figure 12 - Micropipette results at 1 μL with reference value

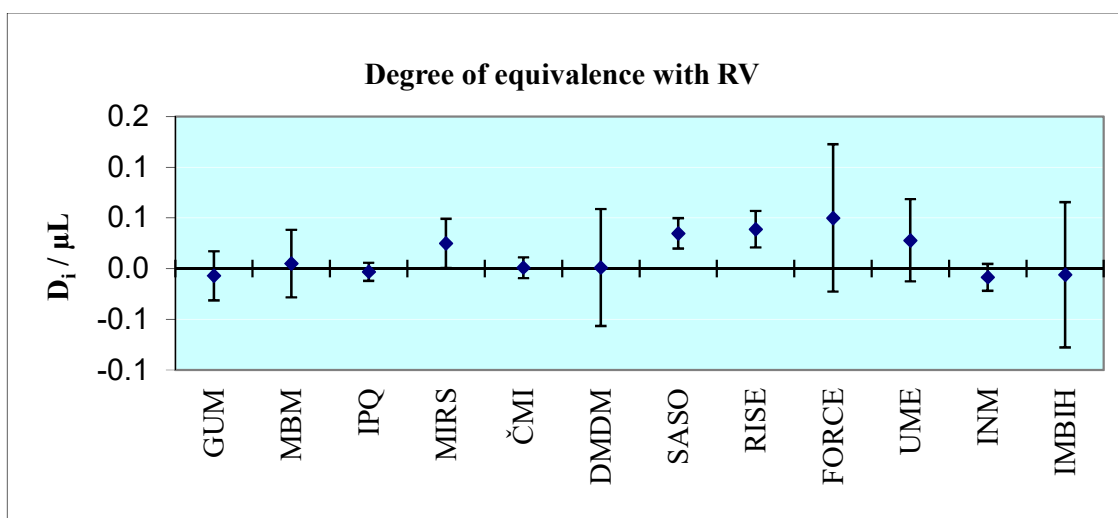


Figure 13 – Degree of equivalence micropipette results at 1 μL

Table 10. Degree of equivalence with RV

Laboratory	$D_i(\mu\text{L})$	$Ud_i(\mu\text{L})$	E_i	Info
GUM	-0,01	0,02	-0,29	
MBM	0,00	0,03	0,15	
IPQ	0,00	0,01	-0,34	
MIRS	0,02	0,02	1,03	
ČMI	0,00	0,01	0,09	
DMDM	0,00	0,06	0,02	
SASO	0,03	0,02	2,31	Excluded
RISE	0,04	0,02	2,17	Excluded
FORCE	0,05	0,07	0,69	
UME	0,03	0,04	0,69	
INM	-0,01	0,01	-0,64	
IMBIH	-0,01	0,07	-0,08	

9.3.4 0,2 µL

The obtained reference value is 0,236 µL. The expanded uncertainty $U = 2 \times u(y)$ of the reference value is: 0,005 µL. The calculated value $\chi^2(\nu) = 12,59$ is smaller than the observed value $\chi^2_{obs} = 25,80$, this means that the chi-square test failed and the results are not consistent.

After removal one outlier the obtained reference value is 0,227 µL. The expanded uncertainty $U = 2 \times u(y)$ of the reference value is: 0,006 µL. The calculated value $\chi^2(\nu) = 11,07$ is larger than the observed value $\chi^2_{obs} = 4,02$, therefore the set of results are consistent from a statistical point of view and the reference value is accepted.

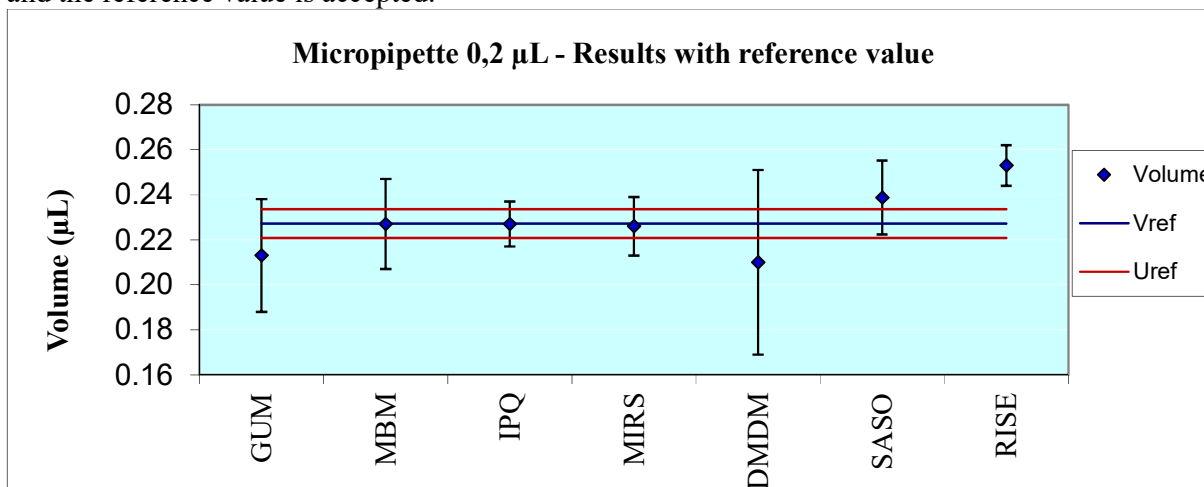


Figure 14 - Micropipette results at 0,2 µL with reference value

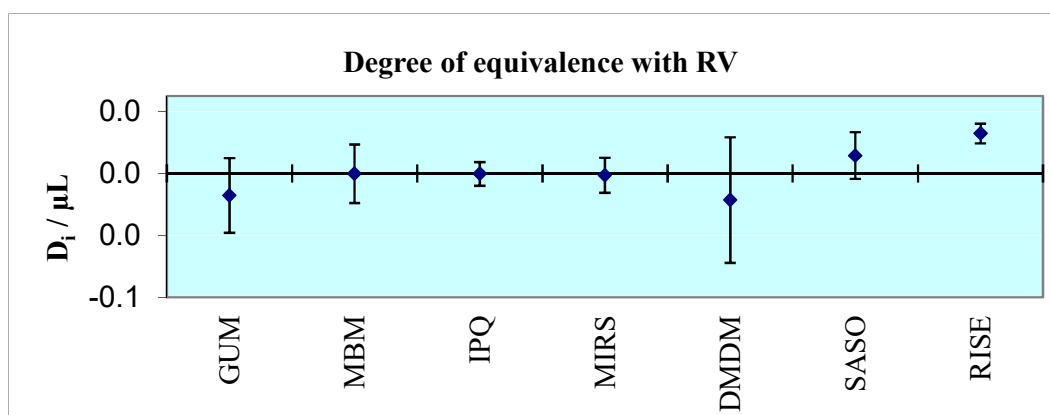


Figure 19 – Degree of equivalence for micropipette results at 0,2 µL

Table 11. Degree of equivalence with RV

Laboratory	$D_i(\mu\text{L})$	$Ud_i(\mu\text{L})$	E_i	Info
GUM	-0,01	0,02	-0,59	
MBM	0,00	0,02	-0,01	
IPQ	0,00	0,01	-0,03	
MIRS	0,00	0,01	-0,11	
DMDM	-0,02	0,04	-0,43	
SASO	0,01	0,02	0,76	
RISE	0,03	0,01	4,08	Excluded

10 Uncertainty calculation

It was requested that all participants present their uncertainty calculations based on the GUM [9].

10.1 Uncertainty components for syringe

Quantity (x_i)	GUM	MBM	IPQ	BFKH	MIRS	DMDM
Repeatability measurements (mL)	0.000093	2.54E-04	0.000277	1.580E-04	4.71E-04	5.61E-04
Mass (g)	0.000003	1.65E-05	4.1056E-06	8.529E-05	1.00E-05	2.77E-05
Air Density (g/mL)	0.000002	1.94E-06	9.836E-07	1.756E-06	9.14E-07	3.40E-07
Water Density (g/mL)	-0.000010	-4.19E-06	-2.905E-05	-2.512E-06	1.10E-05	-1.89E-05
Density of the mass pieces (g/mL)	0.000001	1.30E-06	6.4951E-07	1.116E-05	1.30E-06	1.36E-06
Cub. coeff. of expansion from the glass syringe material ($^{\circ}\text{C}^{-1}$)	0.00000002	-7.04E-07	-5.792E-09	-2.505E-06	4.95E-07	6.00E-07
Water temperature ($^{\circ}\text{C}$)	-0.000001	-6.08E-07	-1.625E-06	4.900E-08	2.07E-06	-9.81E-07
Meniscus reading (mL)	0.000833	1.44E-03	0.0001732	2.886E-03	5.10E-04	8.33E-04
Evaporation (mL)	0.000004	-	2.0785E-06	1.0E-04	6.87E-07	-
Other	0.001247	-	0.00095	-	1.88E-03	-
Combined uncertainty/mL	0,0015	0,0015	0.00100496	0,003	0,002	0,001
Expanded uncertainty/mL	0,003	0,003	0.002	0,006	0,004	0,002

Quantity (x_i)	SASO	RISE	FORCE	UME	INM	IMBIH
Repeatability measurements (mL)	1.36E-04	4.26E-04	0.000861	3.054E-04	2.569E-04	8.140E-05
Mass (g)	1.75E-04	8.52E-05	3.51E-05	3.683E-05	9.006E-04	3.570E-05
Air Density (g/mL)	6.20E-05	2.54E-06	5.02E-06	1.270E-06	4.714E-08	4.773E-07
Water Density (g/mL)	-1.00E-06	-2.89E-05	5.82E-06	3.158E-06	2.832E-06	1.371E-05
Density of the mass pieces (g/mL)	1.00E-06	5.20E-07	-	5.090E-07	1.052E-04	1.214E-06
Cub. coeff. of expansion from the glass syringe material ($^{\circ}\text{C}^{-1}$)	-1.00E-07	-7.51E-07	9.25E-07	2.519E-08	8.500E-06	3.506E-07
Water temperature ($^{\circ}\text{C}$)	-2.90E-06	-2.86E-08	1.69E-05	5.788E-07	3.393E-06	2.692E-06
Meniscus reading (mL)	1.54E-03	2.89E-03	3.72E-06	1.059E-03	7.506E-03	-
Evaporation (mL)	2.90E-05	-2.89E-05	5.80E-05	3.416E-05	2.801E-05	-
Other	-	-	9.97E-04	-	-	1.000E-03
Combined uncertainty/mL	0.0015	0.003	0.0023	0.001	0.001	0.001
Expanded uncertainty/mL	0.003	0.006	0.005	0.002	0.002	0.002

10.2 Uncertainty components piston burette

10.2.1 Uncertainty components for 50 mL piston burette

Quantity (x_i)	GUM	MBM	IPQ	BFKH	MIRS	ČMI
Repeatability measurements (mL)	0.000366	6.71E-04	0.0014158	2.672E-04	1.73E-03	0.002
Mass (g)	0.000217	1.32E-04	0.000134	8.524E-05	1.13E-03	0.0006
Air Density (g/mL)	0.000088	1.51E-04	4.8982E-05	8.763E-05	4.63E-05	0.000065
Water Density (g/mL)	-0.000504	-2.90E-04	-0.0014481	-1.250E-04	5.42E-04	0.000023
Density of the mass pieces (g/mL)	0.000032	6.58E-05	3.2344E-05	2.846E-06	6.52E-05	0.000027
Cub. coeff. of expansion from the piston burette material ($^{\circ}\text{C}^{-1}$)	0.000080	-2.20E-04	-9.875E-05	-3.000E-03	1.39E-04	0.000175
Water temperature ($^{\circ}\text{C}$)	-0.000815	-4.23E-04	-0.000449	-6.000E-05	9.32E-04	0.000202
Resolution of the piston burette (mL)	0.002887	2.89E-03	0.0028867	2.900E-03	2.89E-03	0.002887
Other	0.001680	1.44E-03	-	-	2.52E-03	0.009881
Combined uncertainty/mL	0.0035	0.0034	0.0036	0.004	0.0045	0.010
Expanded uncertainty/mL	0.006	0.007	0.007	0.008	0.009	0.021

Quantity (x_i)	DMDM	SASO	RISE	VSL	FORCE	UME
Repeatability measurements (mL)	0.0017	1.09E-03	0.001717	0.0009	3.7107E-03	1.043E-03
Mass (g)	2.69E-05	1.57E-03	0.000085	0.0015	3.5100E-05	1.565E-04
Air Density (g/mL)	0.0000	3.08E-03	0.000127	0.0000	2.5090E-04	6.342E-05
Water Density (g/mL)	-0.0005	-4.63E-05	-0.001445	0.0000	2.9060E-04	1.580E-04
Density of the mass pieces (g/mL)	0.0001	2.61E-05	0.000026	0.0000	²²	2.542E-05
Cub. coeff. of expansion from the piston burette material ($^{\circ}\text{C}^{-1}$)	-0.0001	-3.20E-04	-0.000405	0.0000	7.7270E-04	4.521E-05
Water temperature ($^{\circ}\text{C}$)	-0.0005	-3.47E-03	-0.001039	0.0000	2.2000E-03	3.466E-03
Resolution of the piston burette (mL)	0.00289	2.89E-03	0.004082	0.0041	5.8000E-03	2.887E-03
Other	-	-	-	0.0016	2.9004E-03	-
Combined uncertainty/mL	0.003405	0.0057985	0.0048	0.0047	0.00784	0.00464
Expanded uncertainty/mL	0.0068	0.0116	0.0096	0.0094	0.016	0.0093

Quantity (x_i)	INM	IMBIH
Repeatability measurements (mL)	0.001768738	6.665E-04
Mass (g)	0.004748260	1.140E-03
Air Density (g/mL)	0.000001970	2.385E-05
Water Density (g/mL)	0.000266510	2.605E-04
Density of the mass pieces (g/mL)	0.000105255	6.066E-05
Cub. coeff. of expansion from the piston burette material ($^{\circ}\text{C}^{-1}$)	0.000120402	4.533E-04
Water temperature ($^{\circ}\text{C}$)	0.000311385	2.756E-03
Resolution of the piston burette (mL)	0.003023243	2.887E-03
Other	-	5.000E-03
Combined uncertainty/mL	0.0059	0.007
Expanded uncertainty/mL	0.012	0.013

²² Included in mass

10.3 Uncertainty components for micropipette

10.3.1 Uncertainty components for 10 μL micropipette

Quantity (x_i)	GUM	MBM	IPQ	MIRS	ČMI	DMDM
Repeatability measurements (μL)	0.000958	3.46E-03	0.00833	6.01E-03	0.012	0.016
Mass (mg)	0.002166	1.65E-02	0.00274	5.06E-03	0.003358	0.0064
Air Density (mg/ μL)	0.000018	7.53E-06	0.00001	9.05E-09	0.000013	3.32E-09
Water Density (mg/ μL)	-0.000101	-4.04E-05	-0.00029	1.08E-07	0.000005	-0.00032
Density of the mass pieces (mg/ μL)	0.000006	1.32E-05	0.00001	1.29E-08	0.000005	0.000013
Cub. coeff. of expansion from the micropipette material ($^{\circ}\text{C}^{-1}$)	0.000010	-9.47E-05	-0.00013	3.61E-08	0.000005	-3.55E-08
Water temperature ($^{\circ}\text{C}$)	-0.000245	-3.75E-05	-0.00075	3.34E-07	0.000041	3.52E-07
Handling of micropipette (μL)	0.010000	0.01	0.00580	4.04E-03	0.005772	0.0058
Evaporation (μL)	0.001200	-	0.00069	7.63E-05	0	0.01
Other	0.007412	-	0.00289	3.34E-03	0.002775	0.02
Combined uncertainty/ μL	0.013	2.0E-02	0.011	0.0095	0.014	0.03
Expanded uncertainty/ μL	0.025	0.04	0.023	0.02	0.028	0.06

Quantity (x_i)	SASO	RISE	FORCE	UME	INM	IMBIH
Repeatability measurements (μL)	6.33E-03	0.021550	0.023300	0.006	0.0012687	3.36E-03
Mass (mg)	1.85E-03	0.001630	3.5106E-05	0.020	0.0064022	3.569E-02
Air Density (mg/ μL)	1.43E-03	0.000025	5.0469E-08	1.294E-05	-1.231E-10	4.918E-06
Water Density (mg/ μL)	-8.00E-06	-0.000289	5.8474E-08	3.153E-05	-5.612E-09	5.195E-05
Density of the mass pieces (mg/ μL)	5.00E-06	5.20E-06	²³	5.186E-06	1.3136E-06	1.251E-05
Cub. coeff. of expansion from the micropipette material ($^{\circ}\text{C}^{-1}$)	-5.40E-05	-0.0006647	7.29465E-08	1.254E-06	9.3619E-10	3.006E-05
Water temperature ($^{\circ}\text{C}$)	-7.00E-04	- 0.0000069 36	3.45935E-07	0.00014	-1.910E-05	1.281E-03
Handling of micropipette (μL)	5.77E-03	0.00577	5.02E-06	0.00577	0.0057735	1.000E-02
Evaporation (μL)	2.33E-02	-0.00289	5.8357E-06	0.000637	0.0028950 70	-
Other	-	-	-	-	4.4323E-07	-
Combined uncertainty/ μL	0.024914	0.023	0.043	0.022	0.0091822	0.037
Expanded uncertainty/ μL	0.0498	0.046	0.086	0.043	0.0184	0.074

²³ Included in mass

10.3.2 Uncertainty components for 5 μL micropipette

Quantity (x_i)	GUM	MBM	IPQ	MIRS	ČMI	DMDM
Repeatability measurements (μL)	0.001574	2.55E-03	0.00360	4.98E-03	0.0086	0.0097
Mass (mg)	0.002166	1.65E-02	0.00273	5.04E-03	0.003358	0.0064
Air Density (mg/ μL)	0.000009	9.81E-06	0.00000	4.52E-09	0.000006	2.0E-09
Water Density (mg/ μL)	-0.000050	-2.00E-05	-0.00025	5.41E-08	0.000002	-1.21E-07
Density of the mass pieces (mg/ μL)	0.000003	6.56E-06	0.00000	6.44E-09	0.000003	7E-09
Cub. coeff. of expansion from the micropipette material ($^{\circ}\text{C}^{-1}$)	0.000005	-4.33E-05	-0.00007	7.62E-09	0.000003	-0.000008
Water temperature ($^{\circ}\text{C}$)	-0.000121	-1.87E-05	-0.00036	2.35E-07	0.000021	-0.00013
Handling of micropipette (μL)	0.005000	0.005	0.00290	2.02E-03	0.002884	0.00288
Evaporation (μL)	0.001200	-	0.00121	3.82E-05	0	0.02
Other	0.011099	-	0.00289	5.17E-03	0.001387	0.017
Combined uncertainty/ μL	0.013	2E-02	0.006	0.0090	0.0095	0.029
Expanded uncertainty/ μL	0.025	0.04	0.013	0.018	0.019	0.059

Quantity (x_i)	SASO	RISE	FORCE	UME	INM	IMBIH
Repeatability measurements (μL)	1.46E-03	0.01318	0.022900	0.006	0.0026722	3.897E-03
Mass (mg)	8.29E-04	0.00173	3.5106E-05	0.020	0.0064833	3.569E-02
Air Density (mg/ μL)	0.000715	1.272E-05	2.5210E-08	6.463E-06	-1.037E-07	2.452E-06
Water Density (mg/ μL)	-4.00E-06	-1.445E-04	2.92E-08	1.575E-05	-4.017E-06	2.589E-05
Density of the mass pieces (mg/ μL)	3.00E-06	2.601E-06	²⁴	2.591E-06	0.0006526	6.235E-06
Cub. coeff. of expansion from the micropipette material ($^{\circ}\text{C}^{-1}$)	-4.20E-05	-0.0003468	9.37E-16	6.263E-07	-1.998E-06	2.097E-05
Water temperature ($^{\circ}\text{C}$)	-3.49E-04	3.47E-06	1.26E-07	0.00007	-9.548E-06	5.760E-04
Handling of micropipette (μL)	2.88E-03	2.89E-03	0.0000029	0.00289	0.0028868	5.000E-03
Evaporation (μL)	0.014203	-2.89E-03	0.0000029	0.000811	0.0028950	-
Other	-	-	-	-	1.1644E-07	-
Combined uncertainty/ μL	0.014612	0.014	0.042	0.021	0.0081434	0.036
Expanded uncertainty/ μL	0.029	0.028	0.084	0.042	0.0163	0.073

10.3.3 Uncertainty components for 1 μL micropipette

Quantity (x_i)	GUM	MBM	IPQ	MIRS	ČMI	DMDM
Repeatability measurements (μL)	0.001723	2.74E-03	0.00360	3.43E-03	0.0047	0.009
Mass (mg)	0.002166	1.65E-02	0.00274	5.02E-03	0.003358	0.0064
Air Density (mg/ μL)	0.000002	5.24E-07	0.00000	9.40E-10	0.000001	3E-10
Water Density (mg/ μL)	-0.000010	-4.04E-06	-0.00005	1.12E-08	0.0000005	-2.6E-08
Density of the mass pieces (mg/ μL)	0.000001	1.32E-06	0.00000	1.34E-09	0.000001	1.3E-09

²⁴ Included in mass

Cub. coeff. of expansion from the micropipette material ($^{\circ}\text{C}^{-1}$)	0.000001	-8.50E-06	-0.00001	4.46E-09	0.000001	-1.36E-06
Water temperature ($^{\circ}\text{C}$)	-0.000028	-3.77E-06	-0.00007	4.09E-08	0.000004	-2.94E-05
Handling of micropipette (μL)	0.001000	0.001	0.00059	4.04E-03	0.00058	0.0006
Evaporation (μL)	0.001200	-	0.00115	7.63E-05	0	0.02
Other	0.012176	-	0.00289	1.00E-02	0.0002788	0.018
Combined uncertainty/ μL	0.013	1.7E-02	0.006	0.0125	0.006	0.029
Expanded uncertainty/ μL	0.025	0.034	0.011	0.025	0.012	0.058

Quantity (x_i)	SASO	RISE	FORCE	UME	INM	IMBIH
Repeatability measurements (μL)	2.19E-03	8.49E-03	0.009900	0.003	0.001767	3.082E-03
Mass (mg)	5.90E-04	1.63E-03	3.511E-05	0.020	0.006483	3.569E-02
Air Density (mg/ μL)	1.48E-04	2.66E-06	5.289E-09	1.328E-06	-4.681E-08	4.917E-07
Water Density (mg/ μL)	-1.00E-06	-2.89E-05	6.127E-09	3.237E-06	-7.087E-07	5.188E-06
Density of the mass pieces (mg/ μL)	1.00E-06	5.49E-07	²⁵	5.324E-07	0.0001305	1.251E-06
Cub. coeff. of expansion from the micropipette material ($^{\circ}\text{C}^{-1}$)	3.00E-06	-7.51E-05	6.115E-09	1.287E-07	-7.932E-07	5.076E-06
Water temperature ($^{\circ}\text{C}$)	-7.20E-05	-7.23E-07	-1.817E-08	0.00001	-1.906E-06	7.985E-05
Handling of micropipette (μL)	5.77E-04	5.77E-04	0.00000061	0.00058	0.000577	1.000E-03
Evaporation (μL)	7.79E-03	-2.89E-03	6.115E-07	0.000811	0.002895	-
Other	-	-	-	-	1.1732E-08	-
Combined uncertainty/ μL	0.0082	0.0091	0.036	0.020	0.0073	0.036
Expanded uncertainty/ μL	0.016	0.019	0.073	0.041	0.015	0.072

10.3.4. Uncertainty components for 0,2 μL micropipette

Quantity (x_i)	GUM	MBM	IPQ	MIRS
Repeatability measurements (μL)	0.0008970	1.30E-03	0.00267	1.32E-03
Mass (mg)	0.0021664	7.92E-03	0.00273	5.02E-03
Air Density (mg/ μL)	0.0000004	1.15E-07	0.00000	1.99E-10
Water Density (mg/ μL)	-0.000002	-9.17E-07	-0.00001	2.38E-09
Density of the mass pieces (mg/ μL)	0.0000001	2.98E-07	0.00000	2.83E-10
Cub. coeff. of expansion from the micropipette material ($^{\circ}\text{C}^{-1}$)	0.0000003	-2.34E-06	0.00000	2.43E-10
Water temperature ($^{\circ}\text{C}$)	-0.000005	-8.47E-07	-0.00001	3.94E-09
Handling of micropipette (μL)	0.0002000	0.0002	0.00013	8.08E-05
Evaporation (μL)	0.0012000	-	0.00115	7.63E-05
Other	0.0122586	-	0.00289	3.67E-03
Combined uncertainty/ μL	0.013	0.01	0.005	0.0064
Expanded uncertainty/ μL	0.025	0.02	0.010	0.013

²⁵ Included in mass

Quantity (x_i)	DMDM	SASO	RISE
Repeatability measurements (μL)	0.005	2.68E-03	2.9738E-03
Mass (mg)	6.4E-03	5.78E-04	1.6300E-03
Air Density (mg/ μL)	7E-11	3.40E-05	6.3580E-06
Water Density (mg/ μL)	5E-09	-2.00E-07	-7.2250E-06
Density of the mass pieces (mg/ μL)	2.8E-10	1.00E-07	1.3005E-07
Cub. coeff. of expansion from the micropipette material ($^{\circ}\text{C}^{-1}$)	-2E-07	-1.00E-06	-1.7340E-05
Water temperature ($^{\circ}\text{C}$)	-5.73E-06	-1.70E-05	-1.7629E-07
Handling of micropipette (μL)	1.15E-04	1.32E-04	1.7300E-04
Evaporation (μL)	1.5E-02	7.74E-03	-2.8900E-03
Other	1.1E-02	-	-
Combined uncertainty/ μL	0.02	0.00821	0.0045
Expanded uncertainty/ μL	0.041	0.0164	0.009

11 CMCs

The following table summarizes the uncertainty claims as published in the KCDB and those given by the participants of this comparison.

Table 12. Expanded standard uncertainty claims as stated by the participants for this comparison and as published in the KCDB (CMCs).

		This comparison		Published in the KCDB
		U	$U / \%$	CMCs (%)
GUM	Syringe, 1 mL	0,003 mL	0,3	-
	Piston burette, 5 mL	0,0058 mL	0,11	-
	Piston burette, 25 mL	0,0062 mL	0,025	
	Piston burette, 50 mL	0,007 mL	0,014	
	Micropipette, 0,2 μL	0,025 μL	12,5	-
	Micropipette, 1 μL	0,025 μL	2,5	
	Micropipette, 5 μL	0,025 μL	0,5	
	Micropipette, 10 μL	0,025 μL	0,25	
MBM	Syringe, 1 mL	0,003 mL	0,3	-
	Piston burette, 5 mL	0,007 mL	0,14	-
	Piston burette, 25 mL	0,007 mL	0,028	
	Piston burette, 50 mL	0,007 mL	0,014	
	Micropipette, 0,2 μL	0,02 μL	10	-
	Micropipette, 1 μL	0,034 μL	3,4	
	Micropipette, 5 μL	0,04 μL	0,8	
	Micropipette, 10 μL	0,04 μL	0,4	
IPQ	Syringe, 1 mL	0,002 mL	0,2	0,02
	Piston burette, 5 mL	0,0062 mL	0,124	0,02

	Piston burette, 25 mL	0,0073 mL	0,03	0,02
	Piston burette, 50 mL	0,0071 mL	0,0142	0,02
	Micropipette, 0,2 µL	0,01 µL	5	-
	Micropipette, 1 µL	0,011 µL	1,1	0,3
	Micropipette, 5 µL	0,013 µL	0,26	0,3
	Micropipette, 10 µL	0,023 µL	0,23	0,3
BFKH	Syringe, 1 mL	0,006 mL	0,6	-
	Piston burette, 5 mL	0,006 mL	0,12	-
	Piston burette, 25 mL	0,007 mL	0,028	
	Piston burette, 50 mL	0,008 mL	0,016	
	Micropipette, 0,2 µL	Not measured		-
	Micropipette, 1 µL			
	Micropipette, 5 µL			
	Micropipette, 10 µL			
MIRS	Syringe, 1 mL	0,004 mL	0,4	-
	Piston burette, 5 mL	0,0028 mL	0,056	-
	Piston burette, 25 mL	0,008 mL	0,032	
	Piston burette, 50 mL	0,009 mL	0,018	
	Micropipette, 0,2 µL	0,013 µL	6,5	-
	Micropipette, 1 µL	0,025 µL	2,5	-
	Micropipette, 5 µL	0,018 µL	0,36	-
	Micropipette, 10 µL	0,02 µL	0,2	0,6
ČMI	Syringe, 1 mL	Not measured		0,3
	Piston burette, 5 mL	0,0066 mL	0,1324	0,3
	Piston burette, 25 mL	0,012 mL	0,048	
	Piston burette, 50 mL	0,021 mL	0,042	
	Micropipette, 0,2 µL	Not measured		-
	Micropipette, 1 µL	0,012 µL	1,2	0,3
	Micropipette, 5 µL	0,019 µL	0,38	
	Micropipette, 10 µL	0,028 µL	0,28	
DMDM	Syringe, 1 mL	0,002 mL	0,2	-
	Piston burette, 5 mL	0,005 mL	0,1	0,06
	Piston burette, 25 mL	0,009 mL	0,036	0,06
	Piston burette, 50 mL	0,008 mL	0,016	0,06
	Micropipette, 0,2 µL	0,041 µL	20,5	-
	Micropipette, 1 µL	0,058 µL	5,8	-
	Micropipette, 5 µL	0,059 µL	1,18	-
	Micropipette, 10 µL	0,06 µL	0,6	0,6
SASO	Syringe, 1 mL	0,003114 mL	0,31	-
	Piston burette, 5 mL	0,005909 mL	0,118	-
	Piston burette, 25 mL	0,007636 mL	0,03	
	Piston burette, 50 mL	0,011597 mL	0,023	
	Micropipette, 0,2 µL	0,01642 µL	8,21	-
	Micropipette, 1 µL	0,016278 µL	1,628	
	Micropipette, 5 µL	0,029223 µL	0,584	
	Micropipette, 10 µL	0,049828 µL	0,498	
RISE	Syringe, 1 mL	0,0058 mL	0,58	-
	Piston burette, 5 mL	0,0082 mL	0,164	-

	Piston burette, 25 mL	0,0086 mL	0,034	
	Piston burette, 50 mL	0,0096 mL	0,019	
	Micropipette, 0,2 µL	0,009 µL	4,5	-
	Micropipette, 1 µL	0,019 µL	1,9	0,4
	Micropipette, 5 µL	0,028 µL	0,56	0,4
	Micropipette, 10 µL	0,046 µL	0,46	0,4
VSL	Syringe, 1 mL	Not measured		-
	Piston burette, 5 mL	0,0084 mL	0,168	Not clearly specified.
	Piston burette, 25 mL	0,0086 mL	0,034	
	Piston burette, 50 mL	0,0094 mL	0,019	
	Micropipette, 0,2 µL	Not measured		
	Micropipette, 1 µL			
	Micropipette, 5 µL			
	Micropipette, 10 µL			
FORCE	Syringe, 1 mL	0,0047 mL	0,47	Not clearly specified.
	Piston burette, 5 mL	0,012 mL	0,24	
	Piston burette, 25 mL	0,015 mL	0,06	
	Piston burette, 50 mL	0,016 mL	0,032	
	Micropipette, 0,2 µL	Not measured		
	Micropipette, 1 µL	0,073 µL	7,3	
	Micropipette, 5 µL	0,084 µL	1,68	
	Micropipette, 10 µL	0,086 µL	0,86	
UME	Syringe, 1 mL	0,002206 mL	0,221	-
	Piston burette, 5 mL	0,00593 mL	0,119	
	Piston burette, 25 mL	0,00687 mL	0,027	
	Piston burette, 50 mL	0,00927 mL	0,0185	
	Micropipette, 0,2 µL	Not measured		-
	Micropipette, 1 µL	0,041 µL	4,1	
	Micropipette, 5 µL	0,042 µL	0,84	
	Micropipette, 10 µL	0,043 µL	0,43	0,8
INM	Syringe, 1 mL	0,001886 mL	0,189	-
	Piston burette, 5 mL	0,00598 mL	0,120	-
	Piston burette, 25 mL	0,00812 mL	0,033	
	Piston burette, 50 mL	0,00592 mL	0,012	
	Micropipette, 0,2 µL	Not measured		-
	Micropipette, 1 µL	0,01468 µL	1,468	
	Micropipette, 5 µL	0,01629 µL	0,326	
	Micropipette, 10 µL	0,0184 µL	0,184	
IMBIH	Syringe, 1 mL	0,002008 mL	0,201	-
	Piston burette, 5 mL	0,006 mL	0,12	0,3
	Piston burette, 25 mL	0,008 mL	0,032	-
	Piston burette, 50 mL	0,013 mL	0,026	
	Micropipette, 0,2 µL	Not measured		-
	Micropipette, 1 µL	0,072 µL	7,2	
	Micropipette, 5 µL	0,073 µL	1,46	
	Micropipette, 10 µL	0,074 µL	0,74	

12 Conclusions

Apart from the delays and some other organization issues, the piston – operated volumetric apparatus have shown an enough good stability to consider this comparison useful to support the CMCs of the participants.

The syringe was tested by 12 laboratories.

All laboratories present results that are consistent with the reference value and with each other, and with $E_n < 1$.

The piston burette was tested by 14 laboratories.

Regarding 5 mL measurements, all laboratories present results that are consistent with the reference value and with each other, and with $E_n < 1$.

Regarding 25 mL measurements, result from one NMI was not used to calculate reference value. There is one laboratory that presented slightly discrepant value when compared with the reference value and one laboratory that has inconsistent result.

Regarding 50 mL measurements, results from two NMIs were not used to calculate reference value. There are two laboratory that presented slightly discrepant values when compared with the reference value.

The micropipette in range from (1 - 10) μL was tested by 12 laboratories. 7 laboratories performed measurements in 0,2 μL nominal value.

Regarding 10 μL measurements, all laboratories present results that are consistent with the reference value, and with each other. There are two laboratories that presents slightly discrepant values when compared with the reference value.

Regarding 5 μL measurements, all laboratories present results that are consistent with the reference value, and with each other. There are three laboratories that presents slightly discrepant value when compared with the reference value.

Regarding 1 μL measurements, results from two NMIs were not used to calculate reference value. There is one laboratory that presents slightly discrepant value when compared with the reference value.

Regarding 0,2 μL measurements, results from one NMI was not used to calculate reference value. All other laboratories present results that are consistent with the reference value, with each other and with $E_n < 1$.

The uncertainty values presented are quite similar for all laboratories in all instruments.

13 References

- [1] [CIPM MRA-G-11](#), Version 1.1, 2021 Measurement comparisons in the CIPM MRA - Guidelines for organizing, participating and reporting;
- [2] ISO 8655-1/2/3/6/9:2022, Piston-operated volumetric apparatus²⁶;
- [3] ISO 4787:2021; Laboratory glass and plastic ware. Volumetric instruments. Methods for testing of capacity and for use;
- [4] ASTM E542:2000 – Standard practice for calibration of laboratory volumetric apparatus;
- [5] Guideline DKD-R 8-1; Calibration of piston-operated pipettes with air cushion, 12/2011;
- [6] Guideline DKD-R 8-3; Calibration of single stroke dispensers and piston burettes, 03/2020;
- [7] Guidelines on the Determination of Uncertainty in Gravimetric Volume Calibration, EURAMET Calibration Guide No. 19, Version 3.0, 09/2018;

²⁶ NMI's and Accredited laboratories are advised to use part 6 for calibration method since it's the reference method.

- [8] Tanaka, M., et. al; Recommended table for the density of water between 0 °C and 40 °C based on recent experimental reports, Metrologia, 2001, Vol.38, 301-309;
- [9] JCGM 100:2008; Evaluation of measurement data – Guide to the expression of uncertainty in measurement;
- [10] M.G. Cox, The evaluation of key comparison data, Metrologia, 2002, Vol. 39, 589-595.

Annex 1- Equipment information for all laboratories

GUM, Glass syringe

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler-Toledo	XPE26PC	22 g	0,000001 g
Thermometer for water measurement	ASL	F100	0 °C to 80 °C	0,001 °C
Thermometer for air measurement	LAB-EL	LB 701	-45 °C to 85 °C	0,01 °C
Barometer	LAB-EL	LB 706B	700 hPa to 1100 hPa	0,1 hPa
Hygrometer	LAB-EL	LB 701	0 % to 99,9 %	0,1%
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Ultra-pure water	Tanaka	0,06 µS/cm

Air temperature (°C)	20,27
Pressure (hPa)	1004,5
Humidity (%)	63,8
Air Density (g/mL)	0,001186

GUM, Micropipette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler-Toledo	XPE26PC	22 g	0,000001 g
Thermometer for water measurement	ASL	F100	0 °C to 80 °C	0,001 °C
Thermometer for air measurement	LAB-EL	LB 701	-45 °C to 85 °C	0,01 °C
Barometer	LAB-EL	LB 706B	700 hPa to 1100 hPa	0,1 hPa
Hygrometer	LAB-EL	LB 701	0 % to 99,9 %	0,1%
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Ultra-pure water	Tanaka	0,06 µS/cm

10 µL		5 µL		1 µL		0,2 µL	
Air temperature (°C)	20,27	Air temperature (°C)	20,26	Air temperature (°C)	20,31	Air temperature (°C)	20,26
Pressure (hPa)	1002,1	Pressure (hPa)	1002,1	Pressure (hPa)	1002,1	Pressure (hPa)	1002,1
Humidity (%)	60,1	Humidity (%)	60,2	Humidity (%)	59,9	Humidity (%)	59,9
Air Density (mg/µL)	0,001184	Air Density (mg/µL)	0,001184	Air Density (mg/µL)	0,001184	Air Density (mg/µL)	0,001184

GUM, Piston burette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Sartorius	MC410S	410 g	0,0001 g
Thermometer for water measurement	Anton Paar	CKT 100	0 °C to 80 °C	0,001 °C
Thermometer for air measurement	LAB-EL	LB-700	10 °C to 40 °C	0,01 °C
Barometer	Druck	DPI 141	800 hPa to 1150 hPa	0,01 hPa
Hygrometer	LAB-EL	LB-700	10 % to 95 %	0,1%
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Ultra-pure water	Tanaka	0,06 µS/cm

50 mL		25 mL		5 mL	
Air temperature (°C)	20,22	Air temperature (°C)	20,34	Air temperature (°C)	20,35
Pressure (hPa)	1003,2	Pressure (hPa)	1003,0	Pressure (hPa)	1002,8
Humidity (%)	63,2	Humidity (%)	62,9	Humidity (%)	63,1
Air Density (g/mL)	0,001185	Air Density (g/mL)	0,001184	Air Density (g/mL)	0,001184

MBM, Syringe

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	B334706944	(0-22) g	0,001 mg
Thermometer for water measurement	Testo AG	testo 480 05600480 02632468 02585727	-200 °C - 1370 °C measurement range 15 °C - 26 °C	0,01 °C
Thermometer for air measurement	Testo AG	testo 480 05600480 02632468 02629307	-200 °C - 1370 °C measurement range 15 °C - 26 °C	0,1 °C
Barometer	Testo AG	testo 480 05600480 02632468	700 hPa - 1100 hPa measurement range 850 hPa - 1050 hPa	0,1 hPa
Hygrometer	Testo AG	testo 480 05600480 02632468	0 % - 100 % (35-80) % rh	0,1 % rh
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	water	Type 3 Tanaka	

Air temperature (°C)	22.3
Pressure (hPa)	997.35
Humidity (%)	54.35
Air Density (g/mL)	0.0011701

MBM, Micropipette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	B334706944	(0-22) g	0,001 mg
Thermometer for water measurement	Testo AG	testo 480 05600480 02632468 02585727	-200 °C - 1370 °C measurement range 15 °C - 26 °C	0,01 °C
Thermometer for air measurement	Testo AG	testo 480 05600480 02632468 02629307	-200 °C - 1370 °C measurement range 15 °C - 26 °C	0,1 °C
Barometer	Testo AG	testo 480 05600480 02632468	700 hPa - 1100 hPa measurement range 850 hPa - 1050 hPa	0,1 hPa
Hygrometer	Testo AG	testo 480 05600480 02632468 02629307	0 % - 100 % (35-80) % rh	0,1 % rh
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	water	Type 3 Tanaka	-

10 µL		5 µL		1 µL		0,2 µL	
Air temperature (°C)	21.4	Air temperature (°C)	21.5	Air temperature (°C)	21.6	Air temperature (°C)	21.5
Pressure (hPa)	1007.2	Pressure (hPa)	1006.9	Pressure (hPa)	1006.8	Pressure (hPa)	1007.1
Humidity (%)	56.3	Humidity (%)	56.4	Humidity (%)	56.0	Humidity (%)	56.2
Air Density (mg/µL)	0.001186	Air Density (mg/µL)	0.001185	Air Density (mg/µL)	0.001184	Air Density (mg/µL)	0.001185

MBM, Piston burette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Sartorius	TE214S-OCE 27103805	(0-210) g	0,0001 g
Thermometer for water measurement	Testo AG	testo 480 05600480 61819234 03504917	-200 °C - 1370 °C measurement range 15 °C - 26 °C	0,01 °C
Thermometer for air measurement	Testo AG	testo 480 05600480 61819234 61828074	-200 °C - 1370 °C measurement range 15 °C - 26 °C	0,1 °C
Barometer	Testo AG	testo 480 05600480 61819234	700 hPa - 1100 hPa measurement range 850 hPa - 1050 hPa	0,1 hPa
Hygrometer	Testo AG	testo 480 05600480 61819234 61828074	0 % - 100 % (35-80) % rh	0,1 % rh
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	water	Type 3 Tanaka	-

50 mL		25 mL		5 mL	
Air temperature (°C)	20.6	Air temperature (°C)	20.7	Air temperature (°C)	20.8
Pressure (hPa)	1006.62	Pressure (hPa)	1006.47	Pressure (hPa)	1006.32
Humidity (%)	65.7	Humidity (%)	65.2	Humidity (%)	65.2
Air Density (g/mL)	0.0011873	Air Density (g/mL)	0.0011865	Air Density (g/mL)	0.0011859

IPQ, Syringe

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	AX26	20 g	0,001 mg
Thermometer for water measurement	Luft	XP100	-10 °C to + 60 °C	0,001 °C
Thermometer for air measurement	Rotronic	HP32	0-70 °C	0,01 °C
Barometer	Druck	DPI 142	900 - 1200 hPa	0,01 hPa
Hygrometer	Rotronic	HP32	0-100%	0.01%
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	3	Tanaka	0.05 µS/cm

Air temperature (°C)	20.58
Pressure (hPa)	1013.14
Humidity (%)	55.2
Air Density (g/mL)	0.0012

IPQ, Micropipette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	AX26	20 g	0,001 mg
Thermometer for water measurement	Luft	XP100	-10 °C to + 60 °C	0,001 °C
Thermometer for air measurement	Rotronic	HP32	0-70 °C	0,01 °C
Barometer	Druck	DPI 142	900 - 1200 hPa	0,01 hPa
Hygrometer	Rotronic	HP32	0-100%	0.01%
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	3	Tanaka	0,05 µS/cm

10 µL		5 µL		1 µL		0,2 µL	
Air temperature (°C)	22.94	Air temperature (°C)	22.92	Air temperature (°C)	22.93	Air temperature (°C)	22.88
Pressure (hPa)	1002.36	Pressure (hPa)	1002.45	Pressure (hPa)	1002.27	Pressure (hPa)	1002.25
Humidity (%)	52.57	Humidity (%)	51.88	Humidity (%)	51.52	Humidity (%)	51.15
Air Density (mg/µL)	0.0012	Air Density (mg/µL)	0.0012	Air Density (mg/µL)	0.0012	Air Density (mg/µL)	0.0012

IPQ, Piston burette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Sartorius	CCE2004	2200 g	0,1 mg
Thermometer for water measurement	Luft	XP100	-10 °C to + 60 °C	0,001 °C
Thermometer for air measurement	Rotronic	HP32	0-70 °C	0,01 °C
Barometer	Druck	DPI 142	900 - 1200 hPa	0,01 hPa
Hygrometer	Rotronic	HP32	0-100%	0.01%
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	3	Tanaka	0,05 µS/cm

50 mL		25 mL		5 mL	
Air temperature (°C)	20.41	Air temperature (°C)	20.57	Air temperature (°C)	20.61
Pressure (hPa)	1012.49	Pressure (hPa)	1012.45	Pressure (hPa)	1012.37
Humidity (%)	66.41	Humidity (%)	67.13	Humidity (%)	68.74
Air Density (g/mL)	0.0012	Air Density (g/mL)	0.0012	Air Density (g/mL)	0.0012

BFKH, Syringe

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler	XPR504S	0 - 500 g	0.1 mg
Thermometer for water measurement	Ahlborn	Almemo 1030	0 - 30 °C	0.001 °C
Thermometer for air measurement	Testo	Testo 601	0 - 70 °C	0.1 °C
Barometer	Wallace & Tiernan	Diptron 3 plus	0 - 1100 mbar	0.1 mbar
Hygrometer	Testo	Testo 601	0 - 100 % rH	0.1 % rH
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	deionized water	table	4 µS/cm

Air temperature (°C)	22.5
Pressure (hPa)	990.7
Humidity (%)	30.1
Air Density (g/mL)	0.0011677

BFKH, Micropipette²⁷

BFKH, Piston burette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler	XPR504S	0 - 500 g	0.1 mg
Thermometer for water measurement	Ahlborn	Almemo 1030	0 - 30 °C	0.001 °C
Thermometer for air measurement	Testo	Testo 601	0 - 70 °C	0.1 °C
Barometer	Wallace & Tiernan	Diptron 3 plus	0 - 1100 mbar	0.1 mbar
Hygrometer	Testo	Testo 601	0 - 100 % rH	0.1 % rH
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	deionized water	table	4 µS/cm

50 mL		25 mL		5 mL	
Air temperature (°C)	22.6	Air temperature (°C)	22.7	Air temperature (°C)	22.7
Pressure (hPa)	998.9	Pressure (hPa)	998.5	Pressure (hPa)	998.1
Humidity (%)	25.5	Humidity (%)	25.0	Humidity (%)	25.0
Air Density (g/mL)	0.001177	Air Density (g/mL)	0.0011761	Air Density (g/mL)	0.0011757

MIRS, Syringe

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	XP56	0 g - 52 g	0.001 mg
Thermometer for water measurement	Almemo	Pt100-2 ZA 9030-FS2	10 °C - 40 °C	0.01 °C
Thermometer for air measurement	Almemo	FH A646-E1	10 °C - 70 °C	0.1 °C
Barometer	Almemo	FD A612SA	900 mbar - 1040 mbar	0.1 mbar
Hygrometer	Almemo	FH A646-E1	10 % rH - 95 % rH	0.1 % rH
Other equipment	Conductivity probe Almemo	FY A641 LFL2	0-200 µS/cm	0.1 µS/cm

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Deionised	Tanaka	up to 1.5 µS/cm

Air temperature (°C)	20.15
Pressure (hPa)	990
Humidity (%)	51.6
Air Density (g/mL)	0.001171

MIRS, Micropipette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	XP56	0 g - 52 g	0.001 mg
Thermometer for water measurement	Almemo	Pt100-2 ZA 9030-FS2	10 °C - 40 °C	0.01 °C
Thermometer for air measurement	Almemo	FH A646-E1	10 °C - 70 °C	0.1 °C
Barometer	Almemo	FD A612SA	900 mbar - 1040 mbar	0.1 mbar
Hygrometer	Almemo	FH A646-E1	10 % rH - 95 % rH	0.1 % rH
Other equipment	Conductivity probe Almemo	FY A641 LFL2	0-200 µS/cm	0.1 µS/cm

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Deionised	Tanaka	up to 1.5 µS/cm

10 µL		5 µL		1 µL	
Air temperature (°C)	20.22	Air temperature (°C)	19.22	Air temperature (°C)	20.26
Pressure (hPa)	978.9	Pressure (hPa)	980.3	Pressure (hPa)	986.7
Humidity (%)	52.3	Humidity (%)	52	Humidity (%)	51.9
Air Density (mg/µL)	0.001157	Air Density (mg/µL)	0.001163	Air Density (mg/µL)	0.001166

²⁷ Not measured

MIRS, Piston burette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	XP2004S	0 g - 2300 g	0,1 mg
Thermometer for water measurement	Almemo	Pt100-2 ZA 9030-FS2	10 °C - 40 °C	0,01 °C
Thermometer for air measurement	Almemo	FH A646-E1	10 °C - 70 °C	0,1 °C
Barometer	Almemo	FD A612SA	900 mbar - 1040 mbar	0,1 mbar
Hygrometer	Almemo	FH A646-E1	10 % rH - 95 % rH	0,1 % rH
Other equipment	Conductivity probe Almemo	FY A641 LFL2	0-200 µS/cm	0,1 µS/cm

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Deionised	Tanaka	up to 1,5 µS/cm

50 mL		25 mL		5 mL	
Air temperature (°C)	19.94	Air temperature (°C)	20.09	Air temperature (°C)	20.28
Pressure (hPa)	994.9	Pressure (hPa)	993.2	Pressure (hPa)	990.1
Humidity (%)	52.7	Humidity (%)	52.1	Humidity (%)	51.6
Air Density (g/mL)	0.001177	Air Density (g/mL)	0.0011749	Air Density (g/mL)	0.001171

ČMI, Syringe²⁸

ČMI, Micropipette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	XP 56/M	max. 52000 mg	0,001 mg
Thermometer for water measurement	Greisinger	GMH 3710	(-200 to +200) °C	0,01 °C
Thermometer for air measurement	COMET SYSTEM	D3121	(-10 to +60) °C	0,1 °C
Barometer	Druck	DPI 141	(800 to 1150) hPa	0,01 hPa
Hygrometer	COMET SYSTEM	D3121	(5 to 95) % RH	0,1 % RH
Other equipment	-			

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	deionized	Tanaka	(1 to 2) µS/cm

10 µL		5 µL		1 µL	
Air temperature (°C)	20.15	Air temperature (°C)	20.15	Air temperature (°C)	20.15
Pressure (hPa)	977.805	Pressure (hPa)	977.805	Pressure (hPa)	977.805
Humidity (%)	54.55	Humidity (%)	54.55	Humidity (%)	54.55
Air Density (mg/µL)	0.001156	Air Density (mg/µL)	0.001156	Air Density (mg/µL)	0.001156

ČMI, Piston burette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Sartorius	CP 225D-OCE	max 80 g/220 g	0,00001 g/0,0001 g
Thermometer for water measurement	Greisinger	GMH 3710	(-200 to +200) °C	0,01 °C
Thermometer for air measurement	COMET SYSTEM	D3121	(-10 to +60) °C	0,1 °C
Barometer	Druck	DPI 141	(800 to 1150) hPa	0,01 hPa
Hygrometer	COMET SYSTEM	D3121	(5 to 95) % RH	0,1 % RH
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	deionized	Tanaka	(1 to 2) µS/cm

²⁸ Not measured

50 mL		25 mL		5 mL	
Air temperature (°C)	19.50	Air temperature (°C)	19.50	Air temperature (°C)	19.50
Pressure (hPa)	983.48	Pressure (hPa)	983.48	Pressure (hPa)	983.48
Humidity (%)	51.30	Humidity (%)	51.30	Humidity (%)	51.30
Air Density (g/mL)	0.001166	Air Density (g/mL)	0.001166	Air Density (g/mL)	0.001166

DMDM, Syringe

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Sartorius	GPC-26 CW	(0 - 20) g	0,001 mg
Thermometer for water measurement	Fluke	1523	(-200 - 500) °C	0,001 °C
Thermometer for air measurement	Testo	177 - H1, data logger	(- 20 to +70) °C	0,1 °C
Barometer	Setra	370	(800 – 1100) mbar	0,01 mbar
Hygrometer	Testo	177 - H1, data logger	(0 – 100) %	0,1 %
Other equipment	-	-	-	-

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	3	Tanaka	1,3 µS/cm
Air temperature (°C)	18,26		
Pressure (hPa)	1023,27		
Humidity (%)	39,53		
Air Density (g/mL)	0,0012		

DMDM, Micropipette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Sartorius	GPC-26 CW	(0 - 20) g	0,001 mg
Thermometer for water measurement	Fluke	1523	(-200 - 500) °C	0,001 °C
Thermometer for air measurement	Testo	177 - H1, data logger	(- 20 to +70) °C	0,1 °C
Barometer	Setra	370	(800 – 1100) mbar	0,01 mbar
Hygrometer	Testo	177 - H1, data logger	(0 – 100) %	0,1 %
Other equipment	-	-	-	-

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	3	Tanaka	1,3 µS/cm
10 µL		5 µL	
Air temperature (°C)	20.98	Air temperature (°C)	20.66
Pressure (hPa)	1007.86	Pressure (hPa)	1014.65
Humidity (%)	60.03	Humidity (%)	58.82
Air Density (mg/µL)	0.0012	Air Density (mg/µL)	0.0012
1 µL		0,2 µL	
Air temperature (°C)	20,61	Air temperature (°C)	20,51
Pressure (hPa)	1014,61	Pressure (hPa)	1014,79
Humidity (%)	60,29	Humidity (%)	61,35
Air Density (mg/µL)	0,0012	Air Density (mg/µL)	0,0012

DMDM, Piston burette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Sartorius	GPC-225 CW	(0 - 220) g	0,01 mg
Thermometer for water measurement	Fluke	1523	(-200 - 500) °C	0,001 °C
Thermometer for air measurement	Testo	177 - H1, data logger	(- 20 to +70) °C	0,1 °C
Barometer	Setra	370	(800 – 1100) mbar	0,01 mbar
Hygrometer	Testo	177 - H1, data logger	(0 – 100) %	0,1 %
Other equipment	-	-	-	-

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	3	Tanaka	1,3 µS/cm

50 mL		25 mL		5 mL	
Air temperature (°C)	20.39	Air temperature (°C)	20.21	Air temperature (°C)	20.27
Pressure (hPa)	1007.86	Pressure (hPa)	1007.64	Pressure (hPa)	1007.63
Humidity (%)	51.07	Humidity (%)	50.38	Humidity (%)	50.83
Air Density (g/mL)	0.0012	Air Density (g/mL)	0.0012	Air Density (g/mL)	0.0012

SASO, Syringe

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Sartorius	I	Max 6100 mg	0.001 mg
Thermometer for water measurement	TOMSON	Pt100	(-)100...+300°C	0.001 °C
Thermometer for air measurement	Vaisala	303	-40 ...+80 °C	0.1 °C
Barometer	Vaisala	303	500 ... 1100 hPa	0.1 hPa
Hygrometer	Vaisala	303	0...100 %RH	0.1 %RH
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Distilled water	Density Meter	1 µS/cm

Air temperature (°C)	20.62
Pressure (hPa)	949.5
Humidity (%)	52.34
Air Density (g/mL)	0.0011207

SASO, Micropipette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Sartorius	I	Max 6100 mg	0.001 mg
Thermometer for water measurement	TOMSON	Pt100	(-)100...+300°C	0.001 °C
Thermometer for air measurement	Sartorius	YCM20MC-DAkks	18°C ≤ t ≤ 27°C	0.01
Barometer	Sartorius	YCM20MC-DAkks	00 hPa ≤ p ≤ 1100 hPa	0.01
Hygrometer	Sartorius	YCM20MC-DAkks	30% ≤ hr ≤ 70%	0.1
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Distilled water	NMCC-SASO	1 µS/cm

10 µL		5 µL		1 µL		0,2 µL	
Air temperature (°C)	20.74	Air temperature (°C)	21.02	Air temperature (°C)	20.02	Air temperature (°C)	20.33
Pressure (hPa)	939.82	Pressure (hPa)	940.46	Pressure (hPa)	937.56	Pressure (hPa)	938.46
Humidity (%)	56.23	Humidity (%)	54.03	Humidity (%)	50.53	Humidity (%)	45.33
Air Density (mg/µL)	0.001108	Air Density (mg/µL)	0.001108	Air Density (mg/µL)	0.001109	Air Density (mg/µL)	0.001109

SASO, Piston burette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Sartorius	I	Max. 1200 g	0.1 mg
Thermometer for water measurement	TOMSON	Pt100	(-)100...+300°C	0.001 °C
Thermometer for air measurement	Vaisala	303	-40 ...+80 °C	0.1 °C
Barometer	Vaisala	303	500 ... 1100 hPa	0.1 hPa
Hygrometer	Vaisala	303	0...100 %RH	0.1 %RH
Other equipment				

Other Informations

		Type	Density reference	Measured conductivity (if the liquid is	
Calibration liquid		Distilled water	NMCC-SASO	1 μS/cm	
50 mL		25 mL		5 mL	
Air temperature (°C)	20.72	Air temperature (°C)	19.91	Air temperature (°C)	20.11
Pressure (hPa)	947.9	Pressure (hPa)	951.4	Pressure (hPa)	948.9
Humidity (%)	55.71	Humidity (%)	49.14	Humidity (%)	50.14
Air Density (g/mL)	0.001118	Air Density (g/mL)	0.001126	Air Density (g/mL)	0.001122

RISE, Syringe

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	XPR205	0-220g	0,01 mg
Thermometer for water measurement	Unisystem	U241	-73 - +135 $^{\circ}\text{C}$	0,001 $^{\circ}\text{C}$
Thermometer for air measurement	Testo	610	-10 - +50 $^{\circ}\text{C}$	0,1 $^{\circ}\text{C}$
Barometer	Druck	DPI140	950-1050 hPa	0,01 mbar
Hygrometer	Testo	610	0-100% RH	0.1%
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	De-ionized water, filtered through Easypure UV and then put under vacuum by a ejector to remove air from the water	Tanaka	0,4 $\mu\text{S/cm}$
Air temperature ($^{\circ}\text{C}$)	23.5		
Pressure (hPa)	998.96		
Humidity (%)	51.3		
Air Density (g/mL)	0.001167171		

RISE, Micropipette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	XPR10	0-10g	0,001 mg
Thermometer for water measurement	Unisystem	U241	-73 - +135 $^{\circ}\text{C}$	0,001 $^{\circ}\text{C}$
Thermometer for air measurement	Dostmann	P755	-200- +850 $^{\circ}\text{C}$	0,01 $^{\circ}\text{C}$
Barometer	Druck	DPI140	950-1050 hPa	0,01 mbar
Hygrometer	Testo	610	0-100% RH	0.1%
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	De-ionized water, filtered through Easypure UV and then put under vacuum by a ejector to remove air from the water	Tanaka	0,5 $\mu\text{S/cm}$

10 μL		5 μL		1 μL		0,2 μL	
Air temperature (°C)	23.12	Air temperature (°C)	23.15	Air temperature (°C)	23.10	Air temperature (°C)	23.23
Pressure (hPa)	977.16	Pressure (hPa)	976.48	Pressure (hPa)	976.46	Pressure (hPa)	977.19
Humidity (%)	43.5	Humidity (%)	44.1	Humidity (%)	44.1	Humidity (%)	43.0
Air Density (mg/μL)	0.00114393	Air Density (mg/μL)	0.001142902	Air Density (mg/μL)	0.0011431	Air Density (mg/μL)	0.001143574

RISE, Piston burette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	XPR205	0-220g	0,01mg
Thermometer for water measurement	Unisystem	U241	-73 - +135°C	0,001°C
Thermometer for air measurement	Testo	610	-10 - +50°C	0,1°C
Barometer	Druck	DPI140	950-1050 hPa	0,01 mbar
Hygrometer	Testo	610	0-100% RH	0,1%
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	De-ionized water, filtered through Easypure UV and then put under vacuum by a ejector to remove air from the water	Tanaka	0,5 µS/cm

50 mL		25 mL		5 mL	
Air temperature (°C)	23.2	Air temperature (°C)	23.4	Air temperature (°C)	23.2
Pressure (hPa)	997.79	Pressure (hPa)	997.57	Pressure (hPa)	997.60
Humidity (%)	46.4	Humidity (%)	47.5	Humidity (%)	48.2
Air Density (g/mL)	0.001168	Air Density (g/mL)	0.001166	Air Density (g/mL)	0.001167

VSL, Syringe²⁹

VSL, Micropipette³⁰

VSL, Piston burette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	AG245	0-210 g	0,0001 g
Thermometer for water measurement	BEAMEX	MC 5-IS	-10-60 °C	0,01 °C
Thermometer for air measurement	Novasina	Hygrodat	15-30 °C	0,1 °C
Barometer	Drück	DPI142	935-1065 hPa	0,001 hPa
Hygrometer	Novasina	Hygrodat	30-70 % rh	0,1%
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Demineralised water	998.206	--

50 mL		25 mL		5 mL	
Air temperature (°C)	20.3	Air temperature (°C)	20.3	Air temperature (°C)	20.4
Pressure (hPa)	1002.6	Pressure (hPa)	1004.7	Pressure (hPa)	1000.7
Humidity (%)	63.6	Humidity (%)	61.7	Humidity (%)	64.7
Air Density (g/mL)	0.00118	Air Density (g/mL)	0.00119	Air Density (g/mL)	0.00118

FORCE, Syringe

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler-Toledo	AX205	80 / 221 g	0,00001 / 0,0001 g
Thermometer for water measurement	Goldbrand	Hg	0 - 50°C	0,1 °C
Thermometer for air measurement	Goldbrand	Hg	0 - 50°C	0,1 °C
Barometer	Präzisions Aneroid Barometer		870 - 1050 hPa	0,5 hPa
Hygrometer	Testo	175-H2	0 - 100%RH	0,001
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Distilled water	Anton Paar 4500	2,86 µS/cm

²⁹ Not measured

³⁰ Not measured

Air temperature (°C)	21.78
Pressure (hPa)	1016.9
Humidity (%)	54
Air Density (g/mL)	0.001198

FORCE, Micropipette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler-Toledo	UMT5	5 g	0.000001
Thermometer for water measurement	Goldbrand	Hg	0 - 50°C	0,1 °C
Thermometer for air measurement	Goldbrand	Hg	0 - 50°C	0,1 °C
Barometer	Präzisions Aneroid Barometer		870 - 1050 hPa	0,5 hPa
Hygrometer	Testo	175-H2	0 - 100%RH	0.001
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Distilled water	Anton Paar 4500	2,86 µS/cm

10 µL		5 µL		1 µL	
Air temperature (°C)	20.75	Air temperature (°C)	20.68	Air temperature (°C)	20.68
Pressure (hPa)	1004.8	Pressure (hPa)	1004.8	Pressure (hPa)	1004.8
Humidity (%)	51.9	Humidity (%)	52.3	Humidity (%)	54
Air Density (mg/µL)	0.001187	Air Density (mg/µL)	0.001188	Air Density (mg/µL)	0.001188

FORCE, Piston burette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler-Toledo	AX205	80 / 221 g	0,00001 / 0,0001 g
Thermometer for water measurement	Goldbrand	Hg	0 - 50°C	0,1 °C
Thermometer for air measurement	Goldbrand	Hg	0 - 50°C	0,1 °C
Barometer	Präzisions Aneroid Barometer		870 - 1050 hPa	0,5 hPa
Hygrometer	Testo	175-H2	0 - 100%RH	0.001
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Distilled water	Anton Paar 4500	2,86 µS/cm

50 mL		25 mL		5 mL	
Air temperature (°C)	21.58	Air temperature (°C)	21.7	Air temperature (°C)	21.7
Pressure (hPa)	1024.4	Pressure (hPa)	1024.9	Pressure (hPa)	1024.9
Humidity (%)	54	Humidity (%)	55	Humidity (%)	55
Air Density (g/mL)	0.001208	Air Density (g/mL)	0.001208	Air Density (g/mL)	0.001208

UME, Syringe

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Sartorius	ME 235 S	(0 - 230) g	0,01 mg
Thermometer for water measurement	Anton Paar	MKT50	- 260 °C - + 962 °C	0,001 °C
Thermometer for air measurement	Vaisala	PTU301	- 40 °C - + 60 °C	0,1 °C
Barometer	Vaisala	PTU301	500 hPa - 1100 hPa	0,1 hPa
Hygrometer	Vaisala	PTU301	0 % - 100 %	0.1%
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Distilled Water	Tanaka Formula	0,79 µS/cm

Air temperature (°C)	20.15
Pressure (hPa)	993.11
Humidity (%)	61.15
Air Density (g/mL)	0.001174

UME, Micropipette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Sartorius	MCM 21 S	(0 - 21) g	0,001 mg
Thermometer for water measurement	Anton Paar	MKT50	- 260 °C - + 962 °C	0,001 °C
Thermometer for air measurement	Vaisala	PTU301	- 40 °C - + 60 °C	0,1 °C
Barometer	Vaisala	PTU301	500 hPa - 1100 hPa	0,1 hPa
Hygrometer	Vaisala	PTU301	0 % - 100 %	0.1 %
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Distilled Water	Tanaka Formula	0,77 µS/cm

10 µL		5 µL		1 µL	
Air temperature (°C)	20.6	Air temperature (°C)	20.6	Air temperature (°C)	20.6
Pressure (hPa)	45.4	Pressure (hPa)	45.4	Pressure (hPa)	45.4
Humidity (%)	1008.2	Humidity (%)	1008.2	Humidity (%)	1008.2
Air Density (mg/µL)	0.001191	Air Density (mg/µL)	0.001191	Air Density (mg/µL)	0.001191

UME, Piston burette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Sartorius	CCE 1004	(0 - 1200) g	0,1 mg
Thermometer for water measurement	Anton Paar	MKT50	- 260 °C - + 962 °C	0,001 °C
Thermometer for air measurement	Vaisala	PTU301	- 40 °C - + 60 °C	0,1 °C
Barometer	Vaisala	PTU301	500 hPa - 1100 hPa	0,1 hPa
Hygrometer	Vaisala	PTU301	0 % - 100 %	0.1 %
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Distilled Water	Tanaka Formula	0,82 µS/cm

50 mL		25 mL		5 mL	
Air temperature (°C)	20.7	Air temperature (°C)	20.7	Air temperature (°C)	20.7
Pressure (hPa)	994.8	Pressure (hPa)	994.15	Pressure (hPa)	994.25
Humidity (%)	52.3	Humidity (%)	54.15	Humidity (%)	53.8
Air Density (g/mL)	0.001174	Air Density (g/mL)	0.001174	Air Density (g/mL)	0.001173

INM, Syringe

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler - Toledo, Switzerland	MCP1-S / MCP 105	max 101 g	0.01 mg
Thermometer for water measurement	Luft, Germany	C110	(0 ... 50) °C	0.01 °C
Thermometer for air measurement	Comet, Czech	D 4130	(0 ... 50) °C	0.1 °C
Barometer	Comet, Czech	D 4130	(800 ... 1100) hPa	0.1 hPa
Hygrometer	Comet, Czech	D 4130	(5 ... 95)%	0.10%
Other equipment	-	-	-	-

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	distilled water	0.9981798 g/mL	3.8 µS/cm

Air temperature (°C)	19.3
Pressure (hPa)	1004.9
Humidity (%)	53.5
Air Density (g/mL)	0.001192036

INM, Micropipette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler - Toledo, Switzerland	MCP1-S / MCP 105	max 101 g	0.01 mg
Thermometer for water measurement	Lufft, Germany	C110	(0 ... 50) °C	0.01 °C
Thermometer for air measurement	Comet, Czech	D 4130	(0 ... 50) °C	0.1 °C
Barometer	Comet, Czech	D 4130	(800 ... 1100) hPa	0.1 hPa
Hygrometer	Comet, Czech	D 4130	(5 ... 95)%	0.10%
Other equipment	-	-	-	-

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	distilled water	0.9981819 mg/μL	1.8 μS/cm

10 μL		5 μL		1 μL	
Air temperature (°C)	20.4	Air temperature (°C)	20.4	Air temperature (°C)	20.4
Pressure (hPa)	1013.6	Pressure (hPa)	1013.6	Pressure (hPa)	1013.5
Humidity (%)	49.7	Humidity (%)	49.1	Humidity (%)	49.8
Air Density (mg/μL)	0.001198075	Air Density (mg/μL)	0.001198165	Air Density (mg/μL)	0.001197644

INM, Piston burette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler - Toledo, Switzerland	MCP1-S / MCP 105	max 101 g	0.01 mg
Thermometer for water measurement	Lufft, Germany	C110	(0 ... 50) °C	0.01 °C
Thermometer for air measurement	Comet, Czech	D 4130	(0 ... 50) °C	0.1 °C
Barometer	Comet, Czech	D 4130	(800 ... 1100) hPa	0.1 hPa
Hygrometer	Comet, Czech	D 4130	(5 ... 95)%	0.10%
Other equipment	-	-	-	-

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	distilled water	0.9981824 mg/μL	3.8 μS/cm

50 mL		25 mL		5 mL	
Air temperature (°C)	19.7	Air temperature (°C)	19.6	Air temperature (°C)	19.3
Pressure (hPa)	1006.2	Pressure (hPa)	1006.4	Pressure (hPa)	1008.5
Humidity (%)	53	Humidity (%)	52.5	Humidity (%)	51.6
Air Density (g/mL)	0.001192152	Air Density (g/mL)	0.001192771	Air Density (g/mL)	0.001196447

IMBIH, Syringe

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	XS 205	0 - 81 g	0.00001 g
Thermometer for water measurement	Testo	735-2	-	0.001 K
Thermometer for air measurement	AHLBORN	FHAD 46-C41	-	0.01 K
Barometer	AHLBORN	FD A612SA	-	0.1 mbar
Hygrometer	AHLBORN	FHAD 46-41	-	0.1%
Other equipment	-	-	-	-

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Distilled water	Tanaka	≤ 5 μS/cm

Air temperature (°C)	22.065
Pressure (hPa)	932.71
Humidity (%)	58.51
Air Density (g/mL)	0.00110

IMBIH, Micropipette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	XS 205	0 - 81 g	0.00001 g
Thermometer for water measurement	Testo	735-2	-	0.001 K
Thermometer for air measurement	AHLBORN	FHAD 46-C41	-	0.01 K
Barometer	AHLBORN	FD A612SA	-	0.1 mbar
Hygrometer	AHLBORN	FHAD 46-41	-	0.1%
Other equipment	-			

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Distilled water	Tanaka	$\leq 5 \mu\text{S/cm}$

10 μL		5 μL		1 μL	
Air temperature ($^{\circ}\text{C}$)	22.22	Air temperature ($^{\circ}\text{C}$)	22.22	Air temperature ($^{\circ}\text{C}$)	21.83
Pressure (hPa)	961.52	Pressure (hPa)	961.75	Pressure (hPa)	961.84
Humidity (%)	58.02	Humidity (%)	53.95	Humidity (%)	54.37
Air Density (mg/ μL)	0.00113	Air Density (mg/ μL)	0.00113	Air Density (mg/ μL)	0.00113

IMBIH, Piston burette

Equipment

	Manufacturer	Type	Range	Resolution
Weighing instrument	Mettler Toledo	XP 1203S	0 - 1200 g	0.001 g
Thermometer for water measurement	Testo	735-2	-	0.001 K
Thermometer for air measurement	AHLBORN	FHAD 46-C41	-	0.01 K
Barometer	AHLBORN	FD A612SA	-	0.1 mbar
Hygrometer	AHLBORN	FHAD 46-41	-	0.1%
Other equipment				

Other Informations

	Type	Density reference	Measured conductivity (if the liquid is water)
Calibration liquid	Distilled water	Tanaka	$\leq 5 \mu\text{S/cm}$

50 mL		25 mL		5 mL	
Air temperature ($^{\circ}\text{C}$)	22.04	Air temperature ($^{\circ}\text{C}$)	21.883	Air temperature ($^{\circ}\text{C}$)	22.154
Pressure (hPa)	931.65	Pressure (hPa)	931.87	Pressure (hPa)	932.17
Humidity (%)	54.1	Humidity (%)	55.29	Humidity (%)	52.68
Air Density (g/mL)	0.00110	Air Density (g/mL)	0.00110	Air Density (g/mL)	0.00110

Annex 2- Burette results for 5 mL and 25 mL

5 mL

The obtained reference value is 5,002 mL. The expanded uncertainty $U = 2 \times u(y)$ of the reference value is: 0,002 mL.

The calculated value $\chi^2(\nu) = 22,36$ is larger than observed value $\chi^2_{obs} = 5,04$, therefore the set of results are consistent from a statistical point of view and the reference value is accepted.

All the measurement results, the reference value and its uncertainty are presented in the following figure A1:

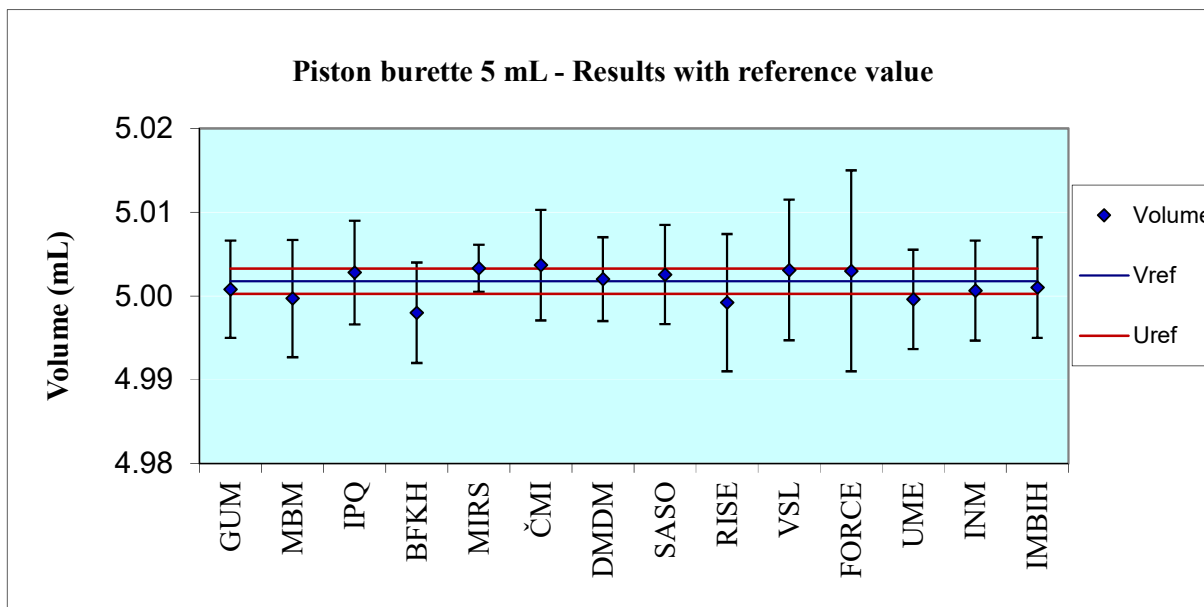


Figure A1 – Piston burette results at 5 mL with reference value

The degree of equivalence with the RV is presented in figure A2:

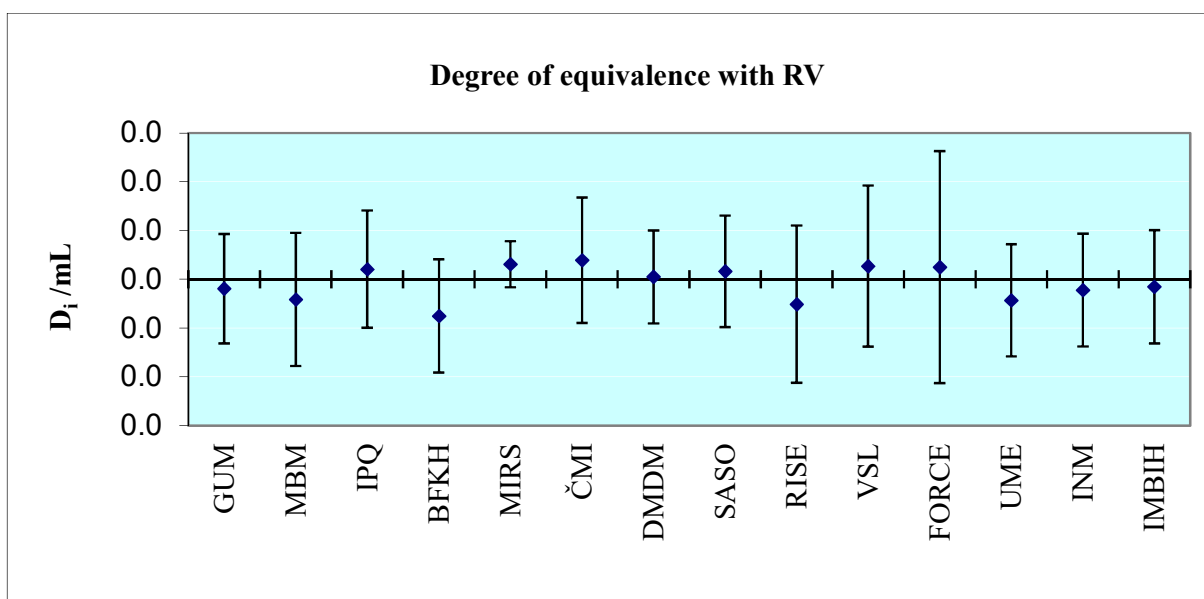


Figure A2 – Degree of equivalence burette 5 mL

Table A1. Degree of equivalence with RV

Laboratory	$D_i(\text{mL})$	$Ud_i(\text{mL})$	E_i
GUM	-0,001	0,006	-0,17
MBM	-0,002	0,007	-0,30
IPQ	0,001	0,006	0,17
BFKH	-0,004	0,006	-0,65
MIRS	0,002	0,002	0,65
ČMI	0,002	0,006	0,30
DMDM	0,000	0,005	0,05
SASO	0,001	0,006	0,14
RISE	-0,003	0,008	-0,32
VSL	0,001	0,008	0,16
FORCE	0,001	0,012	0,10
UME	-0,002	0,006	-0,38
INM	-0,001	0,006	-0,19
BFKH	-0,001	0,006	-0,13

25 mL

The obtained reference value is 25,001 mL. The expanded uncertainty $U = 2 \times u(y)$ of the reference value is: 0,002 mL.

The calculated value $\chi^2(\nu) = 22,36$ is smaller than observed value $\chi^2_{obs} = 29,38$, this means that the chi-square test failed and the results are not consistent.

After removal one outlier, the obtained reference value is 25,003 mL. The expanded uncertainty $U = 2 \times u(y)$ of the reference value is: 0,002 mL.

The calculated value $\chi^2(\nu) = 21,03$ is larger than observed value $\chi^2_{obs} = 17,63$, therefore the set of results is now consistent from a statistical point of view and the reference value is accepted.

All the measurement results, the reference value and its uncertainty are presented in the following figure :

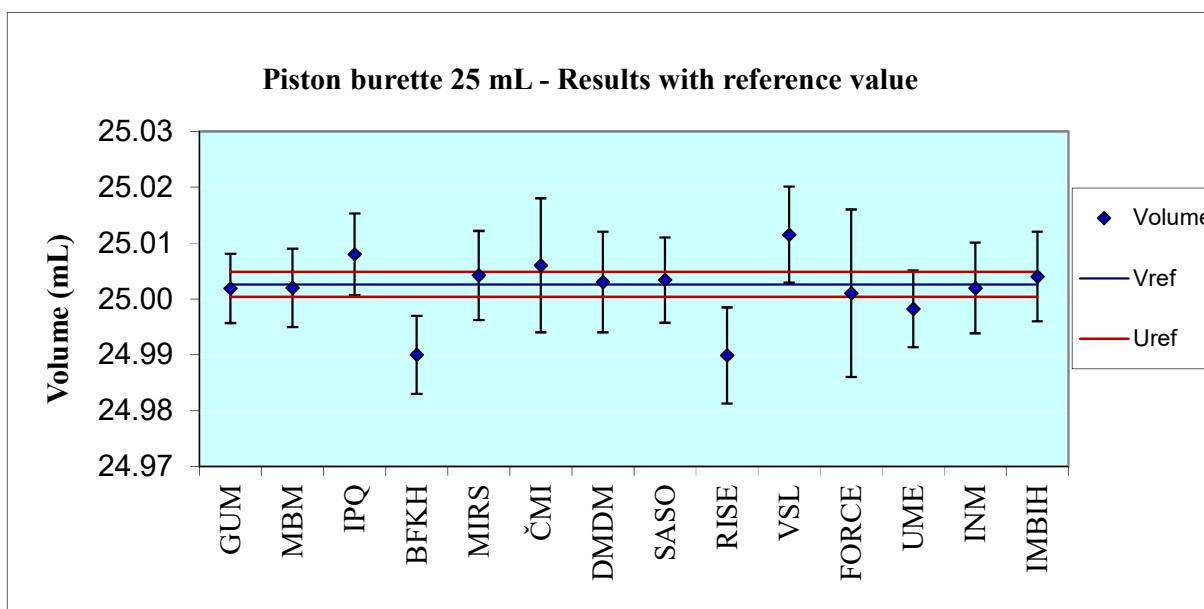


Figure A3 – Burette results at 25 mL with reference value

The degree of equivalence with the RV is presented in figure A4:

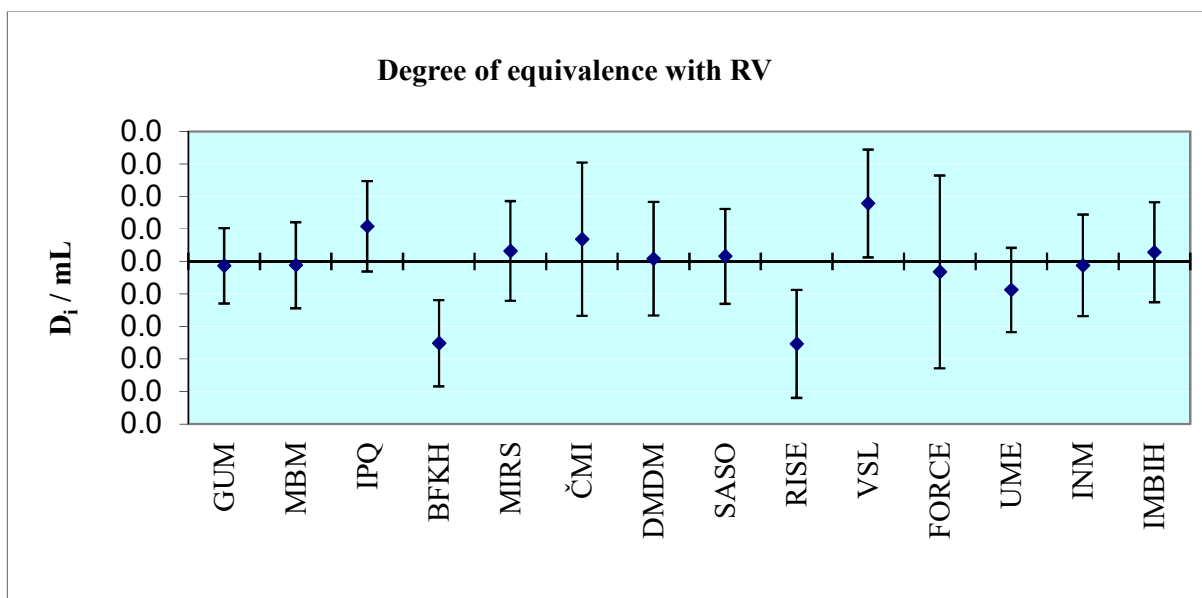


Figure A4 – Degree of equivalence burette 25 mL

Table A2. Degree of equivalence with RV

Laboratory	D_i (mL)	U_{D_i} (mL)	E_i	Info
GUM	-0,001	0,006	-0,12	
MBM	-0,001	0,007	-0,09	
IPQ	0,005	0,007	0,78	
BFKH	-0,013	0,007	-1,90	Excluded
MIRS	0,002	0,008	0,21	
ČMI	0,003	0,012	0,29	
DMDM	0,000	0,009	0,05	
SASO	0,001	0,007	0,11	
RISE	-0,013	0,008	-1,53	
VSL	0,009	0,008	1,07	
FORCE	-0,002	0,015	-0,11	
UME	-0,004	0,006	-0,67	
INM	-0,001	0,008	-0,08	
IMBIH	0,001	0,008	0,18	

Uncertainty components for 5 mL piston burette

Quantity (x_i)	GUM	MBM	IPQ	BFKH	MIRS	ČMI
Repeatability measurements (mL)	0.000356	6.71E-04	0.001126	5.070E-04	1.73E-03	0.001
Mass (g)	0.000217	1.07E-04	5.6057E-05	8.524E-05	1.13E-03	3.14E-05
Air Density (g/mL)	0.000009	4.78E-06	9.8291E-07	8.760E-06	4.63E-05	0.000007
Water Density (g/mL)	-0.000050	-2.96E-05	-0.0002511	-1.254E-05	5.42E-04	0.000002
Density of the mass pieces (g/mL)	0.000003	6.57E-06	3.2321E-06	6.600E-08	6.52E-05	0.000003
Cub. coeff. of expansion from the	0.000005	-3.67E-05	-1.342E-05	-3.000E-04	1.39E-04	0.000018

piston burette material ($^{\circ}\text{C}^{-1}$)						
Water temperature ($^{\circ}\text{C}$)	-0.000111	-9.51E-05	-7.821E-05	-6.000E-06	9.32E-04	0.00002
Resolution of the piston burette (mL)	0.002887	2.89E-03	0.0028867	2.900E-03	2.89E-03	0.002887
Other	0.000168	1.44E-03	-		2.52E-03	0.001246
Combined uncertainty/mL	0.003	3.30E-03	0.0031	0.003	0.0045	0.0033
Expanded uncertainty/mL	0.006	0.007	0.006	0.006	0.009	0.007

Quantity (x_i)	DMDM	SASO	RISE	VSL	FORCE	UME
Repeatability measurements (mL)	0.0018	1.09E-03	3.499E-04	0.0005	3.7107E-03	5.52E-04
Mass (g)	2.69E-05	1.57E-03	8.520E-05	0.0002	3.5100E-05	1.57E-04
Air Density (g/mL)	1.66E-06	3.08E-03	1.272E-05	0.0000	2.5090E-04	6.34E-06
Water Density (g/mL)	-4.63E-05	-4.63E-05	-1.445E-04	0.0000	2.9060E-04	1.58E-05
Density of the mass pieces (g/mL)	6.63E-06	2.61E-05	2.629E-06	0.0000	³¹	2.54E-06
Cub. coeff. of expansion from the piston burette material ($^{\circ}\text{C}^{-1}$)	-6.35E-06	-3.20E-04	-4.046E-05	0.0000	7.7270E-04	4.45E-06
Water temperature ($^{\circ}\text{C}$)	-4.45E-05	-3.47E-03	1.0392E-04	0.0000	2.2000E-03	3.47E-04
Resolution of the piston burette (mL)	0.00289	2.89E-03	4.0825E-03	0.0041	5.8000E-03	2.89E-03
Other	-	-	-	0.0002	2.9004E-03	-
Combined uncertainty/mL	0.0034	0.0057985	0.0041	0.0042	0.00784	0.00296
Expanded uncertainty/mL	0.0068	0.011597	0.0082	0.0084	0.016	0.0059

Quantity (x_i)	INM	IMBIH
Repeatability measurements (mL)	0.000789096	6.173E-04
Mass (g)	0.002496970	1.140E-03
Air Density (g/mL)	0.000000344	2.386E-06
Water Density (g/mL)	0.000008676	2.606E-05
Density of the mass pieces (g/mL)	0.000105604	6.068E-06
Cub. coeff. of expansion from the piston burette material ($^{\circ}\text{C}^{-1}$)	0.000043710	4.943E-05
Water temperature ($^{\circ}\text{C}$)	0.000103796	2.731E-04
Resolution of the piston burette (mL)	0.001432415	2.887E-03
Other	-	5.000E-04
Combined uncertainty/mL	0.00299	0.003
Expanded uncertainty/mL	0.00598	0.006

Uncertainty components for 25 mL piston burette

Quantity (x_i)	GUM	MBM	IPQ	BFKH	MIRS	ČMI
Repeatability measurements (mL)	0.000412	7.29E-04	0.00173772	2.451E-04	1.56E-03	0.001
Mass (g)	0.000217	1.32E-04	0.00008485	8.524E-05	1.07E-03	5.95E-05
Air Density (g/mL)	0.000044	1.95E-05	2.4441E-05	4.377E-05	2.28E-05	0.000033
Water Density (g/mL)	-0.000252	-1.47E-04	-0.001255	-6.269E-05	2.72E-04	0.000011
Density of the mass pieces (g/mL)	0.000016	3.29E-05	1.616E-05	3.330E-07	3.25E-05	0.000014

³¹ Included in mass

Cub. coeff. of expansion from the piston burette material ($^{\circ}\text{C}^{-1}$)	0.000033	-1.49E-04	-6.429E-05	-1.500E-03	2.40E-04	0.000087
Water temperature ($^{\circ}\text{C}$)	-0.000585	-3.16E-04	-0.0003499	-3.000E-05	1.06E-03	0.000101
Resolution of the piston burette (mL)	0.002887	2.89E-03	0.0028868	2.900E-03	2.89E-03	0.002887
Other	0.000840	1.44E-03	-	-	1.59E-03	0.005162
Combined uncertainty/mL	0.0031	3.33E-03	0.0036	0.0035	0.0040	0.006
Expanded uncertainty/mL	0.006	0.007	0.0073	0.007	0.008	0.012

Quantity (x_i)	DMDM	SASO	RISE	VSL	FORCE	UME
Repeatability measurements (mL)	0.0033	4.52E-04	9.6815E-04	0.0008	4.1983E-03	6.605E-04
Mass (g)	2.69E-05	7.87E-04	8.5200E-05	0.0008	3.5100E-05	1.565E-04
Air Density (g/mL)	0.0000	1.55E-03	6.3580E-05	0.0000	1.2540E-04	3.169E-05
Water Density (g/mL)	-0.0004	-2.20E-05	-7.225E-04	0.0000	1.4500E-04	7.922E-05
Density of the mass pieces (g/mL)	0.0000	1.32E-05	1.3294E-05	0.0000	³²	1.270E-05
Cub. coeff. of expansion from the piston burette material ($^{\circ}\text{C}^{-1}$)	-0.0001	-4.35E-05	-1.9941E-04	0.0000	4.2110E-04	3.256E-05
Water temperature ($^{\circ}\text{C}$)	-0.0005	-1.73E-03	-5.1960E-04	0.0000	1.1555E-03	1.733E-03
Resolution of the piston burette (mL)	0.00289	2.89E-03	4.0825E-03	0.0041	5.8000E-03	2.887E-03
Other	-	-	-	0.0008	1.4501E-03	-
Combined uncertainty/mL	0.004396	0.0038179	0.0043	0.0043	0.00741	0.00344
Expanded uncertainty/mL	0.0088	0.0076	0.0086	0.0086	0.015	0.0069

Quantity (x_i)	INM	IMBIH
Repeatability measurements (mL)	0.001095315	7.498E-04
Mass (g)	0.003218630	1.140E-03
Air Density (g/mL)	0.000000907	1.194E-05
Water Density (g/mL)	0.000103091	1.303E-04
Density of the mass pieces (g/mL)	0.000105255	3.035E-05
Cub. coeff. of expansion from the piston burette material ($^{\circ}\text{C}^{-1}$)	0.000120402	2.276E-04
Water temperature ($^{\circ}\text{C}$)	0.000121089	1.092E-03
Resolution of the piston burette (mL)	0.002211838	2.887E-03
Other	-	2.500E-03
Combined uncertainty/mL	0.0041	0.004
Expanded uncertainty/mL	0.0082	0.008

³² Included in mass